



Ontario Geological Survey
Open File Report 6122

**Toward a New Metamorphic
Framework for Gold
Exploration in the
Red Lake Greenstone Belt**

2003





ONTARIO GEOLOGICAL SURVEY

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Toward a New Metamorphic Framework for Gold Exploration in the
Red Lake Greenstone Belt

by

P.H. Thompson

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Abstract

This report summarizes results of the first phase of a project designed to produce a new, belt-scale, metamorphic framework for gold exploration in the Red Lake greenstone belt. Initiated by Yuri Dobrotin (Placer Dome – Campbell Mine), Jack Parker (Ontario Geological Survey), and the author, the first phase is financed by Placer Dome and Ontario Geological Survey (OGS). OGS also provided archived thin sections and sample locations and covered costs of publication. Tom Skulski and Mary Sanborn-Barrie of the Geological Survey of Canada contributed thin sections and sample location data. Peter H. Thompson Geological Consulting Ltd. provided in kind support. Metamorphism has long been recognized as a factor worth considering in the search for new gold deposits in the Red Lake Belt, but comparatively little is known about the regional metamorphic framework and the potential to use metamorphic features as exploration tools. Integrated with the history of deformation, intrusion, alteration and mineralization that has transformed the Red Lake belt, the new metamorphic framework will assist in the evaluation of the relative importance of pre-, syn-, and post-metamorphic gold mineralization and of the possible sources of heat and mineralizing fluids. Metamorphic zones and metamorphic anomalies revealed by this work are in themselves potential exploration targets.

The project area covers all or parts of 14 townships with the majority of the 781 thin sections located in Bateman, McDonough, Balmer, Dome, Fairlie, Todd, Ball, Heyson, and Baird townships. Samples from Graves (1), Willans (1), Byshe (2), Killala (2), and Mulcahy (9) townships are also included. The thin sections were grouped into eight rock associations: 1) metabasites, 2) meta-quartzofeldspathic rocks, 3) meta-ultramafic rocks, 4) metamorphosed aluminum-rich rocks, 5) metamorphosed iron formation, 6) metagranitoids, 7) metamorphosed carbonate-rich rocks, 8) unmetamorphosed granitoids. Documentation of metamorphic grade in a range of compositions ensures that some measure of metamorphic grade is determined for most parts of the study area. The approach permits a more refined breakdown of metamorphic grade at localities where several compositions are present and helps to pin down the grade in areas where only one rock association is present.

Two metamorphic zone boundaries and three types of metamorphic anomaly are prospective for gold. Mapped for the first time in the Red Lake area, the biotite isograd as defined in quartzofeldspathic rocks is close to more than half of the current and past gold mines. A similar spatial relation occurs in the Kalgoorlie region of Western Australia. Linked to gold mineralization at Campbell-Goldcorp by previous workers, the location of the transition from greenstone to amphibolite zones has been modified, thereby outlining new areas of interest. In spite of the wide variation in the density of data constraining the metamorphic zone boundaries across the map area, there is no doubt that three kinds of metamorphic anomaly are evident. There are isolated occurrences of relatively high metamorphic grade rocks in low grade zones and low metamorphic grade rocks in high grade zones and, in some areas, the metamorphic zones narrow dramatically. The apparent spatial relation between previous gold producers and the "hot spot" near Cochenour suggests that the other high grade anomalies should be evaluated for their gold potential. Low grade anomalies are prospective for both intrusive- and deformation zone-related gold deposits. High geothermal gradients evident from closely-spaced zone boundaries can be indicators of high rates of heat and fluid flow and may be conducive to gold mineralization.

This study builds on and enhances the important contributions of previous workers. Further sampling and petrography are required to improve the definition of metamorphic zones outlined in this report and to further test the utility of metamorphic data and concepts as exploration tools.

Toward a New Metamorphic Framework for Gold Exploration in the Red Lake Greenstone Belt

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Introduction

The Red Lake greenstone belt is an important gold camp that has produced approximately 20 million ounces of gold from 1930 to the end of 2002 (Lichtblau et al. 2003). Two mines are currently in production: the Placer Dome North America–Campbell Mine which has been in continuous production since 1949; and the Goldcorp Inc.–Red Lake Mine. The Red Lake gold camp is famous for very high grade gold mineralization such as the High Grade Zone at the Goldcorp Mine where diamond drill intersections of 17.46 ounces gold per ton across 16.4 feet have been reported (Hinz et al. 2000). The gold deposits at Red Lake are similar to quartz-carbonate vein deposits (Robert 1995) associated with deformation and folding in metamorphosed volcanic, sedimentary and granitoid rocks. Deposits at the Campbell and Goldcorp mines may represent shallow-level Archean lode-gold deposits which Gebre-Mariam, Hagemann and Groves (1995) suggest are upper crustal equivalents to deeper "mesothermal" deposits. The past-producing Madsen gold deposit, however, is interpreted by Dubé et al. (2000) as a high temperature gold deposit similar to gold skarns in mafic metavolcanic rocks (Mueller and Groves 1991).

This report and map summarize results of the first phase of a project designed to produce a new, greenstone belt-scale, metamorphic framework for gold exploration in the Red Lake greenstone belt. Initiated by Yuri Dobrotin (Placer Dome – Campbell Mine), Jack Parker (Ontario Geological Survey), and the author, the project is financed by Placer Dome and the Ontario Geological Survey (OGS). OGS also provided archived thin sections and sample locations and covered costs of publication. In the latter stages of the project Peter H. Thompson Geological Consulting Ltd. contributed in kind support. Tom Skulski and Mary Sanborn-Barrie of the Geological Survey of Canada contributed thin sections and sample location data. The methodology applied and the collaboration between industry and government follow from a pilot project completed for Placer Dome (Richard Keele) and the OGS (John Ayer) in the Timmins area of the Abitibi greenstone belt (Thompson 2002b).

Mapping of metamorphic zones and application of concepts derived from metamorphic petrology contribute to the development of gold exploration models in four key areas. First, metamorphic mineral assemblages and textures constrain the timing, duration and depth of deformation and plutonism, two important factors in the formation of many gold deposits. Second, mapping and petrography provide a way of identifying original rock types, stratigraphy, and halos related to pre-metamorphic synvolcanic, porphyry-related gold mineralization. Third, the distribution and intensity of "background" metamorphic grade defines the limits and nature of alteration associated with syn- and post-metamorphic mineralization in deformation zones and in contact metamorphic aureoles of syn-orogenic plutons. Fourth, metamorphic anomalies are prospective because they develop in zones where high heat flow occurs and where the volume of hydrous fluids rich in CO_2 is relatively high. The updated metamorphic data base and district-scale metamorphic zone map, together with the application of metamorphic petrologic concepts, will enhance exploration of known gold deposits and help to define new gold exploration targets in the Red Lake greenstone belt.

Metamorphism has long been recognized as a factor worth considering in the search for new gold deposits in the Red Lake greenstone belt. A pre-metamorphic origin for the gold (Ferguson et al. 1972; Kusmirski and Crocket 1980; Crocket et al. 1981; Kerrich et al. 1981; Penczak 1996; Penczak and Mason 1997) requires metamorphic data and concepts in order to identify the original alteration and mode and style of mineralization. Similarly, given that granitoid plutons in and around the belt range in age from 2734 to 2699 Ma (Corfu and Wallace 1986; Corfu and Andrews 1987; McMaster 1987; Noble 1989; Corfu and Stone 1998), metamorphic data provide constraints on the timing of gold deposits formed directly from magmatic fluids (Bruce 1924; Bruce and Hawley 1927; Horwood 1945). Rigg (1980) and Rigg and Helmstaedt (1981) emphasized structural control on formation of the Campbell/Goldcorp gold

deposits but invoked syn-deformational metamorphism as the source of the mineralizing fluids that deposited gold in the vicinity of the transition from greenschist to amphibolite facies metamorphism. Numerous studies have linked gold mineralization to regional metamorphism and belt-scale deformation and assumed that these processes are caused by intrusion of plutons around and within the Red Lake greenstone belt (Mathieson 1982; Pirie 1982; Andrews and Wallace 1983; Durocher and Burchell 1983; Durocher and Hugon 1983; Lavigne 1983; Andrews 1984; Mathieson and Hodgson 1984; Andrews and Hugon 1985; Christie 1986; Andrews et al. 1986; Colvine et al. 1988; Tarnocai and Hattori 1996; Damer 1997; Menard and Pattison 1998; Tarnocai 2000; and Dubé et al. 2000). The model proposed by MacGeehan and Hodgson (1982; Hodgson and MacGeehan 1981) involving the deposition of gold before, during and after the attainment of peak metamorphic conditions also depends on documentation of the metamorphic history of the deposits. Which hypothesis or combination of hypotheses should be incorporated into current gold exploration models remains controversial.

Important questions have yet to be answered. Most of the references cited in the previous paragraph refer to work in and around the Campbell, Goldcorp and past-producing Madsen mines. To what extent are these studies relevant to exploration elsewhere in the belt? Comparatively little is known about the belt-scale distribution of metamorphic zones and about the potential use of metamorphic features as exploration tools. Previous workers invoke granitoids as the principal source of heat for metamorphism, but some plutons are too old and others too young to explain the regional metamorphic pattern. Alternatively, both granitoids and regional metamorphism may be products of crustal extension (volcano-sedimentary basin formation) followed by crustal shortening and thickening (orogenesis) as proposed for low pressure metamorphic terranes elsewhere (Thompson 1989a; 1989b). That is, heat from the mantle and from radiogenic decay in a thicker than normal crust caused metamorphism and syn-orogenic granitoids. The geometry and age of the metamorphic zones is critical for determination of sources of mineralizing fluids and of the configuration of fluid flow. Integrated with the history of deformation, intrusion, alteration and mineralization that has transformed the Red Lake greenstone belt, the new metamorphic framework will assist in the evaluation of the relative importance of pre-, syn-, and post-metamorphic gold mineralization and of the possible sources of heat and mineralizing fluids. Furthermore, metamorphic zone boundaries and metamorphic anomalies revealed by this work are in themselves potential exploration targets.

Terminology

Metamorphism refers to the changes of mineralogy and texture that occur when a sedimentary, igneous or metamorphic rock is subjected to physical conditions (temperature, pressure, fluid composition) that are different from those when the rock first formed.

Metamorphic grade is a relative measure of the intensity or completeness of metamorphism. The changes occur in minerals making up the rock (mineral assemblages), in textures (grain size and shape, relationships between mineral grains), and in structures (planar and linear aggregates of minerals such as cleavage, foliations, folds, veins, compositional layering that are pervasive throughout the rock). Variations in grade are evident at the scale of the map, outcrop or thin section.

An **isograd** is a line or surface of constant metamorphic grade. It is commonly mapped as the first appearance of a mineral or mineral assemblage in rocks of similar composition.

In general, and neglecting the addition or subtraction of small amounts of water or carbon dioxide, **rock composition** does not change during metamorphism. Rocks of different composition such as shales, basalt, and tonalite respond differently to increasing metamorphic grade. This means that specific

stratigraphic markers or pre-metamorphic hydrothermal alteration zones can be mapped from the lowest to highest grades in metamorphic terranes. Furthermore, variations of mineral assemblage with composition at constant grade mean each rock type develops a distinctive set of isograds. Although fluid composition variations may complicate the picture, in general, isograds in different compositions are concordant.

Regional metamorphism occurs across thousands of square kilometres and lasts tens of millions of years. It is caused by the heating and deformation of rocks during events that shorten and thicken the crust beyond a normal value of 35 km (orogenesis).

Contact metamorphism is the result of heating near an igneous intrusion. Duration is in the range of thousands to hundreds of thousands of years. Contact metamorphic zones are typically centimetres to a kilometre or two thick.

Hydrothermal metamorphism (metasomatism/alteration) involves the movement of volatile and non-volatile elements in and out of a rock. Typically structurally-controlled and of limited distribution (centimetres to hundreds of metres), the time frame of alteration is likely to be similar to that for contact metamorphism, but could be of long duration as well.

Metamorphic zones are descriptive features mapped on the basis of characteristic minerals or mineral assemblages in rocks of similar composition (e.g., greenstone zone in metabasalt/gabbro, knotted schist zone in aluminous metasedimentary rocks).

A **metamorphic facies** refers to a range of temperature and pressure that has produced characteristic mineral assemblages in a variety of rock compositions. For example, upper greenschist facies is defined by the occurrence of chlorite-epidote-actinolite-albite in mafic rocks, chlorite-muscovite-biotite in aluminous metasedimentary rocks, talc-calcite in siliceous dolomitic metacarbonates.

Temperature increasing with depth in the crust or with proximity to an igneous body causes the most obvious changes observed in metamorphic rocks. **Pressure** on solid components of rocks increases with depth in the crust at a rate dependent on the average density of overlying rocks (crustal average - 2.80 g/cm^3 , $\sim 0.34 \text{ GPa/km}$, $\sim 0.34 \text{ kbar/km}$). For most natural systems, pressure on the intergranular fluid phase (P_{fluid}) during regional and contact metamorphism is assumed to equal P_{solid} .

P-T diagrams are orthogonal plots of T and P that incorporate the above assumptions about fluid pressure and generally include the assumption that metamorphic fluids are 100 percent water. Plotted on such a diagram, stability fields for key metamorphic mineral assemblages constrain estimates of the P-T conditions of metamorphism. A traverse perpendicular to isograds in a metamorphic terrane is represented on a P-T diagram by an **erosion surface P-T array** (metamorphic field gradient of Turner 1981).

Geothermal gradients are the increase of temperature with depth in the crust. Making an assumption about the average density of the crust, it is possible to relate lithostatic pressure (P_{solid}) to depth and calculate the geothermal gradients implied by metamorphic grade and the magnitude of post-metamorphic **exhumation** (uplift and erosion).

Depth-time diagrams (Thompson 1989a; 1989b, 1999, 2001) illustrate the evolution of metamorphic rocks with respect to changes in temperature and depth (pressure) during deposition, deformation, mineralization, metamorphism and exhumation of greenstone belts.

The "gold deposition zone" (Thompson 1999, 2001, 2002a) is derived from the conclusion of Loucks and Mavrogenes (1999) (they cite Hodgson et al. 1993 and Phillips et al. 1997) that 90 percent of the gold mined from metamorphic terranes around the world was deposited between temperatures of 250° and 450° C and pressures of 1 and 3 kilobars.

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Methodology

The project area covers all or parts of 14 townships in the Red Lake District with the majority of 781 thin sections collected from outcrops in Bateman, McDonough, Balmer, Dome, Fairlie, Todd, Ball, Heyson, and Baird townships. Samples from Graves (1), Willans (1), Byshe (2), Killala (2) and Mulcahy (9) townships are also included. This study is the first systematic analysis of the metamorphic grade of these samples and, where possible, of the intensity of deformation and the type and intensity of alteration.

PETROGRAPHY

Reconnaissance petrography of 781 thin sections is the basis for a) determination of eight rock associations (generalized rock types); b) estimates of the grade of the predominant metamorphic event; c) qualitative measure of the intensity of deformation; d) where possible, qualitative comments, on type, intensity, and timing of alteration with respect to metamorphism. All samples observed are compiled in Table 1 (Appendix 1). A map reference number is included in Table 1 so that users without access to the ArcMap® files can link a data point on the map to Table 1.

ROCK ASSOCIATIONS

Reconnaissance petrography revealed that metamorphic rocks can be divided into seven rock associations (Numbers 1-7 on Figure 1, in back pocket; Table 1) with each one representing a particular range of rock composition. Thin sections of unmetamorphosed granitoid rocks (Number 8 on Figure 1, in back pocket; Table 1) were examined as well. Number 9 on Figure 1 (in back pocket) in the Metamorphic Grade column indicates that the rock association is uncertain. The sequence and spacing of zones on the metamorphic map (Figure 2, in back pocket) are defined on the basis of metamorphic mineral assemblages observed in thin section that change with increasing metamorphic grade in each rock association and from one association to the next. For example, the transition from greenschist to amphibolite facies is, typically, sharp in pelitic rocks (Rock Association 4, see Figure 1, in back pocket); however, in metamorphosed basalts (Rock Association 1) the transition is gradational and the greenschist and amphibolite facies are separated by a transitional zone. Also, the first appearance of biotite occurs at

somewhat lower metamorphic grade in potassium feldspar-chlorite-bearing rocks such as felsic metatuff and quartz-feldspar metaporphry (Rock Association 2) than it does in classic pelitic (aluminous) metasedimentary rocks (Rock Association 4). Documentation of metamorphic grade in a range of compositions, therefore, insures that some measure of metamorphic grade is determined for most parts of the study area. The approach permits a more refined breakdown of metamorphic grade at localities where several compositions are present. The numbers designating each rock association on Figure 1 are also included in Tables 1 and 2, Appendix 1).

METAMORPHIC GRADE

With respect to documentation of variations in metamorphic grade, it is convenient to distinguish metamorphic zone, a descriptive term for a mappable feature defined for a particular rock association, from metamorphic facies, a particular range of temperature and pressure that is characterized by diagnostic mineral assemblages in a number of rock associations. The increase of metamorphic grade for each rock association is represented by a two digit number with the first digit (1 to 9) indicating the rock association. The second number indicates the relative grade of metamorphism (see Figure 1, in back pocket). For example, the number '62' in Figure 1 indicates that the rock association is metamorphosed granulite (6) with a relative metamorphic grade of '2'. The number zero in the second digit indicates a rock association that is not metamorphosed. In the comprehensive data table (781 samples, see Table 1, Appendix 1), the first digit is a nine if the rock association is uncertain and the second digit is a nine if the metamorphic grade is uncertain. The metamorphic map (see Figure 2, in back pocket) is based on a smaller number of data points (598 samples, see Table 2, Appendix 1) that represent the metamorphic grade at each locality. Only the rock association that best constrains the metamorphic zone boundaries is included on the map to reduce clutter at stations on the map face (i.e., in cases where more than one thin section exists for a single rock association and more than one rock association may be present at a station). Samples for which the rock association and/or metamorphic grade are uncertain (see Table 1, Appendix 1) are omitted from Table 2 (see Appendix 1).

ROCK ASSOCIATIONS AND METAMORPHIC GRADE

The metamorphic zones that outline increasing grade in the seven metamorphic rock associations are defined by a series of characteristic metamorphic mineral assemblages. These are described below.

1) Metabasites. Metamorphosed basalt, andesitic basalt, leucogabbro, and gabbro are included in this rock association. Depending on their metamorphic mineral assemblages these rocks are, in fact, greenstones, greenschists, or amphibolites. The assemblage actinolite-epidote-chlorite-albite (see Zone 11, Figure 1, in back pocket) is diagnostic of the greenstones (massive to weakly-foliated) and greenschists (intensely foliated) that are typical of the greenstone zone in metabasalts and metagabbros. On the metamorphic map, the distribution of green circles (see Figure 2, in back pocket) representing these mineral assemblages defines the greenstone zone. With increasing grade, metamorphic hornblende appears in metabasites. Rocks with both hornblende and actinolite and lesser amounts of chlorite and/or epidote are diagnostic of the transition zone in this rock association (see Zone 12, Figure 1, in back pocket). Yellow circles mark the localities where these assemblages occur (see Figure 2, in back pocket). Prograde chlorite and epidote are absent from the lower amphibolite zone metabasites where the characteristic assemblage is hornblende-calcic plagioclase (see Zone 13, Figure 1, in back pocket). The distribution of orange circles outlines the extent of the lower amphibolite zone (see Figure 2, in back pocket). Based on the Horwood's (1945) map in the southernmost part of the project area east of Hatchet Lake, quartz-feldspar leucosomes derived from partial melting of amphibolites under upper amphibolite

zone conditions (see Zone 14, Figure 1; red zone, Figure 2, in back pocket) are inferred to be present. This was not confirmed, however, as no thin sections were obtained from these rocks.

2) Meta-Quartzofeldspathic Rocks. This association consists of metamorphosed sandstone, conglomerate, quartz-feldspar porphyry, rhyolite, and felsic volcanoclastic rocks. The appearance of biotite as a result of reaction between chlorite and potassic white mica and/or potassium feldspar is the key metamorphic boundary in these rocks. It separates chlorite-muscovite/K-feldspar assemblages (see Zone 21, Figure 1, in back pocket) from biotite-bearing rocks (see Zone 22, Figure 1, in back pocket). On the metamorphic map (see Figure 2, in back pocket), pale blue and dark blue squares represent biotite-absent and biotite-present mineral assemblages, respectively. Petrography of these widely distributed rocks is the basis for this new subdivision of the greenstone zone in the Red Lake greenstone belt into lower and upper greenstone zones (see Figures 1 and 2, in back pocket). The division corresponds approximately to the boundary between lower and upper greenschist facies. In many cases, the occurrence of sub-biotite metamorphic grade in rock association 2 is supported by the low-grade mineral assemblages in associations 3 to 7 (see below). Carbonate and white mica can be prominent minerals in the sub-biotite zone (see Zone 21, Figure 1 in back pocket) and lower part of the biotite zone (see Zone 22, Figure 1, in back pocket). Calcium-bearing mineral phases such as epidote and hornblende, that are also present in biotite-bearing quartzofeldspathic rocks, may be the high grade equivalents of the carbonate, white mica, and chlorite. With further work it may be possible to subdivide Zone 22 with an isograd separating lower grade carbonate-white mica-chlorite assemblages (with and without biotite) from higher grade biotite-epidote-hornblende assemblages.

3) Meta-Ultramafic Rocks. More restricted in distribution, metamorphosed ultramafic igneous rocks (meta-komatiite, meta-peridotite) are clearly divided into low grade assemblages (see Zone 31, Figure 1, in back pocket) made up of talc, chlorite, carbonate and opaque minerals and higher grade assemblages (see Zone 32, in back pocket) dominated by amphibole and lacking talc and chlorite. Pale violet and medium violet triangles represent these mineral assemblages on Figure 2 (in back pocket).

4) Metamorphosed Aluminum-Rich Rocks. Classic muscovite-rich pelitic rocks are relatively rare in the sample collection used for this study. Many of the aluminum-rich assemblages are mafic and felsic metavolcanic rocks that were enriched in aluminum during pre-metamorphic, possibly syn-volcanic, hydrothermal alteration (e.g., Penczak and Mason 1997; Dubé et al. 2000). During subsequent regional metamorphism and deformation these rocks were transformed to mineral assemblages ranging from chlorite-white mica (see Zone 41, Figure 1, in back pocket), chloritoid-chlorite-white mica, and biotite-white mica-chlorite, and biotite-garnet-chlorite (Zone 42), staurolite-biotite-garnet, cordierite-orthoamphibole-biotite, and cordierite-biotite-andalusite (Zone 43). Sillimanite was not observed in the thin sections used for this study but is present in the northeastern part of the belt (Parker, personal communication, 2003). Furthermore, it is likely, that partially melted aluminous rocks (Zone 44) occur along the southern and northern limits of the study area. Stars of variable shades of grey to black represent rock association 4 on the metamorphic map (see Figure 2, in back pocket).

5) Metamorphosed Chemical Sedimentary Rocks/Iron Formation. Although volumetrically limited, metamorphosed iron formation is distributed throughout the Red Lake greenstone belt. Some carbonate-rich rocks included in rock association 7 (see below) may also be derived from chemical metasediments. In rock association 5, low grade chlorite-carbonate-quartz-magnetite/sulphide rocks (see Zone 51, Figure 1, in back pocket) can be separated from rocks that contain abundant grunerite/cummingtonite with and without garnet and hornblende (Zone 52). Beige and brown pentagons indicate the occurrence of amphibole-absent and amphibole-bearing metamorphosed iron formation on Figure 2 (in back pocket).

6) Metagranitoid Rocks. Metamorphosed plutonic rocks (granite to tonalite) are present in the study area. At lower grade (Zone 61), fine-grained aggregates of metamorphic chlorite and white mica and

epidote replace igneous biotite, hornblende and calcic plagioclase. At higher grade (Zone 62) fine-grained aggregates of metamorphic biotite (with and without tiny beads of titanite) and epidote occur. Grain size reduction and other evidence of syn-metamorphic deformation are typical in the metagranitoids. Pale and dark pink diamonds represent lower and higher metamorphic grade, respectively, on the metamorphic map (see Figure 2, in back pocket).

7) Metamorphosed Carbonate-Rich Rocks. A number of samples are rich in carbonate or in the higher grade equivalent, calc-silicate minerals (amphibole, clinopyroxene, garnet). The lowest grade assemblages (see Zone 71, Figure 1; pale yellow-green crosses, Figure 2, in back pocket) are made up of variable proportions of chlorite, carbonate, and plagioclase with or without white mica. Commonly these rocks are intensely foliated similar to the chlorite-carbonate schist and phyllite that are characteristic of the high strain/alteration zones associated with Archean gold deposits that occur in deformation zones. In other examples, the rocks look like carbonate veins. At somewhat higher grade (Zone 72, see Figure 1; medium yellow green crosses, see Figure 2, in back pocket), biotite coexists with chlorite and carbonate. Diopside-grossularite-amphibole assemblages represent the highest grades observed (Zone 73, dark yellow-green crosses). Working with a single thin section, it is not easy to determine the protolith of these rocks. Metamorphosed carbonate alteration of metabasalt/gabbro, interpillow material, and carbonate-rich clastic metasedimentary rocks are all possible protoliths.

8) Unmetamorphosed Granitoid Rocks. Several samples included in this study represent the younger, late syn-orogenic granitoids. Biotite, hornblende, and plagioclase in these rocks are essentially unaltered and igneous textures are prominent due to a lack of deformation and recrystallization. Evidence of deformation is rare. The Killala-Baird batholith appears to cut across metamorphic zonation to the west and southeast but elsewhere imposes a contact metamorphic aureole. For these reasons these rocks are designated 80 indicating that they are younger than the main metamorphic event in the Red Lake greenstone belt (see below).

9) Rock Association and Metamorphic Grade Uncertain. There are a small number of samples included in Table 1 (see Appendix 1) with textures and/or mineral assemblages that are sufficiently ambiguous that a rock association and/or metamorphic grade were not determined.

In both cases, the number nine is used to tag these rocks (e.g., 99 indicates neither the association nor the grade have been attributed).

At this point, the relative positions of isograds (metamorphic zone boundaries) as defined in different rock associations in the greenschist facies (see Figure 1, in back pocket) are known only in a qualitative sense. More detailed sampling is required to calibrate these features more precisely. However, the relationships illustrated in Figure 1 are consistent across the greenstone belt.

METAMORPHIC ZONES

The metamorphic zonation (see Figure 2, in back pocket) is inferred from the distribution of variably-coloured symbols that indicate the rock association and corresponding grade for 598 of the thin sections studied (Table 2, Appendix 1). Metamorphic grade and rock association for the other samples are included in Table 1 (see Appendix 1). Boundaries between greenstone, transition and amphibolite zones (see Figure 2, in back pocket) are determined by mineral assemblages in metamorphosed basalt and gabbro (Rock Association 1). The greenstone zone is divided in two by a line marking the appearance of biotite in meta-quartzofeldspathic rocks (Rock Association 2). The upper limit of the greenstone zone (lower limit of the transition zone) is defined by the appearance of hornblende in metabasites containing

the assemblage actinolite-epidote-chlorite-albite. Transition zone metabasites contain both actinolite and hornblende, commonly along with small amounts of chlorite and/or epidote. Amphibolite zone metabasites are made up essentially of hornblende and calcic plagioclase. Metamorphic zones are drawn on the basis of mineral assemblages in the most widely distributed rock associations, metabasites (Rock Association 1) and metamorphosed quartzofeldspathic rocks (Rock Association 2). Wherever possible, metamorphic mineral assemblages in the less widely distributed rock associations were used to further constrain the zone boundaries. Metamorphic zone boundaries are drawn as solid lines on the map (see Figure 2), but it is evident from the variations in data density that the boundaries are only approximate or inferred in some areas. The lower greenstone (blue) and upper greenstone (green), transition (yellow), and lower amphibolite (orange) zones are based on petrographic data (see Figures 1 and 2). The upper amphibolite zone (red) is inferred from Horwood's (1945) geological map. With respect to metamorphic facies, lower and upper greenstone zones correspond approximately to the lower and upper greenschist facies. The greenschist-amphibolite facies boundary occurs within the upper part of the transition zone.

DEFORMATION AND ALTERATION

An attempt was made to include a qualitative record of the degree to which the thin sectioned samples have been deformed and/or changed by hydrothermal alteration (see Table 1, Appendix 1). Even though a single thin section may not be representative of the outcrop from which it came, belt-scale variations in these parameters may be of interest. With respect to deformation, in most cases, weak, moderate and intense (Table 3; see also Table 1, Appendix 1) refer to the extent to which a preferred orientation of minerals and/or mineral aggregates are present in the slide. Generally, the fabric is assumed to be a penetrative planar feature. The possibility that linear fabrics are present cannot be determined with a single thin section. In a small number of rocks, the style of deformation was one dominated by grain size reduction or folding of layering or a pre-existing fabric. The attempt to make qualitative comments on the type, intensity and timing of alteration with respect to metamorphism of these rocks was done with some trepidation. Once again, however, to ignore this aspect of the samples is not appropriate. Table 3 explains the codes used in Table 1 (Appendix 1). Assessment of the regional variation of these features and interpretation of their significance with respect to gold mineralization have not yet been done. It would be useful to compare the distribution of alteration as defined with this data with regional alteration patterns mapped by Parker (2000). Chloritic alteration that postdates main phase metamorphism may be a second retrograde metamorphic event. Abundant weak tourmaline alteration in metasedimentary rocks may be a product of primary sedimentary boron deposition.

Table 3. Legend for deformation and alteration columns in Table 1 (Appendix 1).

DEFORMATION											
w - weak					m - moderate			i - intense			
ALTERATION											
Type					Intensity			Timing			
Chloritic	Potassic	Carbonate	tourmaline	quartz	weak	moderate	intense	pre-meta	syn- to post-meta	post-meta	uncertain
I	2	3	4	5	w	m	I	I	II	III	u

Metamorphic Map

The new belt-scale metamorphic zonation in the Red Lake greenstone belt (see Figure 2, in back pocket) is consistent with the subprovince-scale metamorphic map of Thurston and Breaks (1978). The zonation in the Red Lake greenstone belt outlines an irregular concentric pattern with grade increasing outward from the lower greenstone zone through the upper greenstone, transition, lower amphibolite and upper amphibolite zones. On Figure 2, upper amphibolite zone grade rocks containing evidence of partial melting are inferred toward the south only. The southern limit of such rocks north of the map area is not known.

METAMORPHIC ZONE BOUNDARIES

The boundaries between metamorphic zones (isograds) contribute to estimates of the temperatures and pressures of metamorphism, to reconstruction of the thermal regime (thermal gradients, orientation of isothermal surfaces) when the zones formed, and thereby, to the geometry of fluid flow during metamorphism. Of particular interest to gold exploration in the Red Lake greenstone belt are the biotite isograd that defines the boundary between the lower and upper greenstone zones and the transition zone that separates the upper greenstone and lower amphibolite zones (see Figure 2, in back pocket). In the Kalgoorlie region of Western Australia (Mikucki and Roberts 2003; Hall 1998) and in the Timmins area of the Abitibi Greenstone Belt (Thompson 2002b), there appears to be a spatial relationship between the appearance of biotite in quartzofeldspathic rocks and gold mines. The present study uses the biotite isograd to subdivide, for the first time, low-grade rocks in the Red Lake greenstone belt. The lower boundary of the transition zone at Red Lake corresponds quite well with a blue-green hornblende isograd that is prospective for gold in the Kalgoorlie area (Mikucki and Roberts 2003). The boundary between the greenschist and amphibolite metamorphic facies occurs within the transition zone on Figure 2 (see Figure 1, in back pocket). Previous workers (e.g., Andrews et al. 1986; Lavigne et al. 1986; Damer 1997) noted the proximity of the Campbell and Goldcorp mines to this metamorphic facies boundary. Furthermore, significant changes in the position of the greenschist/amphibolite facies boundary in the eastern part of the belt and previously unrecognized metamorphic anomalies within zones are evident on the new metamorphic map (Figure 2). For example, south of the Campbell-Goldcorp Mines, the boundary, which occurs within the upper part of the transition zone, turns southward within two kilometres and crosses the Chukuni River well to the west of the position indicated by Andrews et al. (1986) and Lavigne et al. (1986, p.176). Furthermore, the current data set (see Figure 2, in back pocket) does not indicate the presence of a tongue of amphibolite facies rocks following the strike of the Austin "Tuff" northeast of Madsen as indicated by Durocher and Hugon (in Lavigne et al. 1986).

METAMORPHIC ANOMALIES

In spite of the wide variation in the density of data constraining the zone boundaries across the map area, there is no doubt that three kinds of metamorphic anomaly are evident (see Figure 2, in back pocket). Isolated occurrences of relatively high grade rocks are present in low grade zones and low grade rocks in high grade zones and, in some areas the metamorphic zones narrow dramatically (i.e., isograds are closely spaced).

Hot Spots. The current data set outlines four prominent and two minor hot spots in the eastern half of the greenstone belt and one small hot spot near the northern edge of the low grade zone in the west half of the belt (see Figure 2, in back pocket). The proximity of the past producing gold mines to the Cochenour high grade anomaly suggests that the others may be highly prospective. The metamorphic anomaly that is located in close proximity to the Cochenour, McKenzie and Gold Eagle mines is

associated with the McKenzie Island pluton. This suggests that the high grade rocks within the anomaly are relicts of the contact aureole that formed around the pluton prior to the peak of low grade regional metamorphism. The prominent anomaly located eight kilometres to the west-southwest, close to the contact of the Dome Stock, may also be explained this way. However, a granitoid is not exposed in the vicinity of the anomalies located east of Slate Bay, at the southwest end of Hoyles Bay, or north of Cochenour (see Figure 2, in back pocket). Alternatively, these hot spots may be related to a structural conduit that focussed upward flow of heat and fluids during regional metamorphism. That is, there is potential for both intrusive-related and metamorphism related gold mineralization.

Cold Spots. Lower to upper greenstone zone anomalies occur along the southern and northeastern parts of the metamorphic zonation in the upper greenstone, transition, and lower amphibolite zones (see Figure 2, in back pocket). In the southeast corner of Hoyles Bay, it is possible that two small anomalies form a linear array related to the north-northeast trending promontory of the lower greenstone zone that is located to the south. The trend and location of these anomalies is close to the Post Narrows deformation zone mapped by Andrews et al. (1986) and Lavigne et al. (1986). The low grade anomalies west and north of Madsen (see Figure 2, in back pocket) can be connected as a curving linear trend. Southeast of Madsen two low metamorphic grade anomalies parallel the main structural trend. Linear arrays of relatively low grade anomalies could result from localized retrograde conditions along planar structures formed during post-metamorphic peak cooling as the rocks were exhumed to the Earth's surface. Alternatively, during peak metamorphic conditions planar structures acted as conduits for CO₂-rich fluids that produced what looks like retrograde mineral assemblages. In this case, prograde metamorphic reactions are reversed near peak temperatures because the lower grade assemblages are stabilized by the high CO₂ content of mineralizing fluids. Isolated "cold spots" such as the one associated with the past producing Buffalo mine (see Figure 2, in back pocket, gold occurrence 15) and the low grade anomalies east of East Bay and east of Balmer Lake may indicate the presence of linear fluid conduits.

Steep Metamorphic Gradients. Changes in the width of metamorphic zones on Figure 2 may be related to changes in the dip of isograds, to increases or decreases in thermal gradients (spacing of isothermal surfaces), or to telescoping of metamorphic grade across faults trending parallel to the metamorphic zones. The absence of data constraining the isograds is also a factor in some areas. However, the Campbell/Goldcorp ore bodies occur near steep metamorphic gradients as do the past producing mines in the vicinity of the high grade anomaly west of Cochenour. Perhaps the relatively high heat and fluid flow is conducive to concentration and deposition of gold. If so, other examples of narrow metamorphic zones in the Red Lake greenstone belt may be prospective for gold.

Metamorphism and Geological Setting

The pressures and temperatures that caused metamorphism, together with the spatial relationships between metamorphic zones and granitoid rocks and major deformation zones contribute to the reconstruction of the geological setting of gold mineralization in the Red Lake greenstone belt. Relationships between rocks, pressure (depth), temperature, metamorphism, plutonism and deformation are illustrated schematically in Figure 3.

METAMORPHIC TEMPERATURES AND PRESSURES

Estimates of the physical conditions prevailing at the time metamorphic zones formed in rocks that are now at the Earth's surface are a means of determining the depth at which metamorphism occurred; the geothermal gradients prevailing at that time; and the magnitude of post-metamorphic uplift and erosion

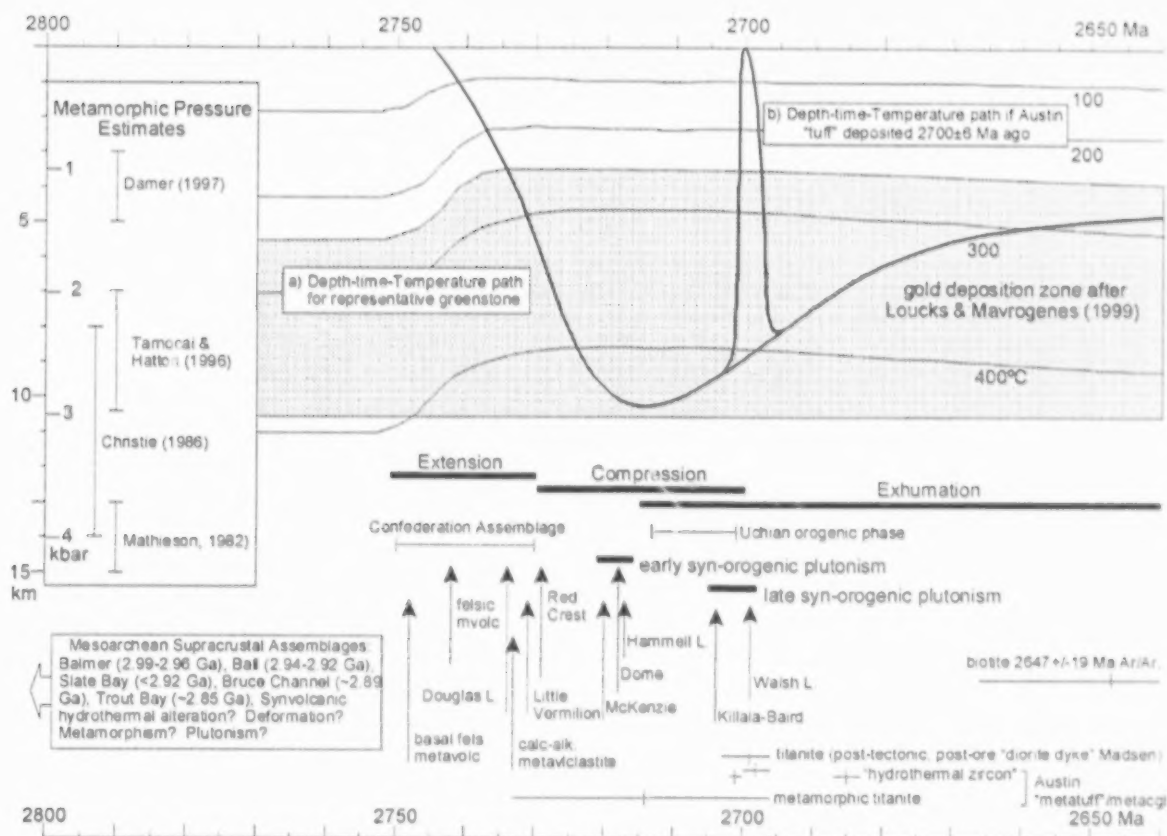


Figure 3. Depth-time diagram (from Thompson 1989) illustrates evolution of a typical greenstone zone metabasite from the Red Lake Greenstone Belt. Duration of extension, compression, and exhumation inferred from age determinations by: Corfu and Andrews 1987; Corfu and Stone 1989; Corfu and Wallace 1986; McMaster 1987; Noble 1989; Sanborn-Barrie et al. 2001.

(exhumation). Regional petrography conducted as part of this project is consistent with earlier observations (Thurston and Breakey 1978; Mathieson 1982; Christie 1986; Tarnocai and Hattori 1996) indicating that the Red Lake belt was subjected to low pressure type regional metamorphism. That is, andalusite was the stable polymorph of Al_2SiO_5 at low and medium grades and maximum pressures were in the range of 2–4 kilobars. This corresponds to depths of burial of 7 to 14 kilometres assuming an average rock density of 2.85g/cm^3 . Metamorphic mineral assemblages are consistent with the temperatures near 400°C at the transition from lower to upper greenstone zone and $500\text{--}550^\circ\text{C}$ at the lower limit of the lower amphibolite zone. The onset of partial melting at the transition to upper amphibolite zone is associated with temperatures greater than 650°C . These combinations of temperatures and pressures correspond to average geothermal gradients to the depths indicated of $40\text{--}60^\circ\text{C/km}$. Post-metamorphic uplift and erosion must have been on the order of 7 to 14 kilometres. The low maximum metamorphic pressures calculated by Damer (1997) (see Figure 3) are unlikely to be correct. Such shallow depths (less than 5 km) are not consistent with either the absence of features characteristic of high level plutonism in the Killala-Baird and Walsh intrusions or biotite cooling ages (2647–2620 Ma; Wright et al. 1991; Hanes and Archibald, 1998) indicating the greenstone belt was deeper than 5 km prior to 2650 Ma. Combining these estimates of metamorphic conditions with other aspects of the geological evolution of the Red Lake greenstone belt (Figure 3) provides a fresh perspective on the origin of the gold deposits.

METAMORPHISM AND GRANITOIDS

As in many low pressure metamorphic terranes around the world, the abundance of granitoid intrusions has led to the assumption that the metamorphic pattern in the Red Lake greenstone belt is a contact effect of the intrusions (Andrews et al. 1986; Menard and Pattison 1998; Tamocai 2000). Similar to the situation in the Archean Slave Province (Thompson et al. 1995), however, the Red Lake metamorphic data are consistent with geological and geochronological relationships indicating that at least some granitoid intrusions are too old or too young to be the heat source for regional metamorphism. For example, plutons overlapping in time with deposition of the Confederation assemblage (Douglas Lake - 2734 Ma, Corfu and Stone 1998; Red Crest - 2729 Ma, Little Vermillion - 2729 Ma, Corfu and Andrews 1987) are clearly too old to be a heat source for belt-scale metamorphic zones that cut across major structures in the belt. Furthermore, regional petrography (see Figure 2, in back pocket) indicates that, whereas the Howey metadiorite and the Dome and McKenzie Island stocks (2718 Ma and 2720 Ma, respectively, Corfu and Andrews 1987) have been overprinted by carbonate alteration (Parker 2000) and metamorphic zonation (see Figure 2, in back pocket). However, some components of the Killala-Baird batholith (2704 Ma, Corfu and Andrews 1987) post-date and cut across the metamorphic zones (see Figure 2, in back pocket). The amphibolite zone rocks east of the Campbell/Goldcorp mines, have been attributed to contact metamorphism (Andrews et al. 1986) related to the intrusion of the Walsh Lake pluton (2699 Ma, Noble 1989). This pluton is a relatively young component of the Trout Lake batholith and similar in age to the youngest phases of the Killala-Baird batholith. In this report (see Figure 3), granitoids are grouped into three main associations: a) late syn-Confederation assemblage age, pre-orogenic plutons, greater than 2730 Ma; b) early syn-orogenic plutons, 2720-2717 Ma; c) late syn-orogenic plutons, 2704-2699 Ma. Although there is no doubt that these intrusions caused localized contact metamorphism in different parts of the belt at different times, it is likely that the Red Lake supracrustal rocks were already undergoing greenschist grade regional metamorphism when intrusion of syn-orogenic granitoids occurred (see Figure 3). Soon after intrusion, early synorogenic granitoids and related contact aureoles cooled off and were overtaken by the ongoing low to medium grade regional metamorphism (see Figure 2, in back pocket). 15 to 20 million years later contact aureoles related to late synorogenic intrusions overprinted adjacent regionally metamorphosed supracrustal rocks and early synorogenic granitoids that were still quite close to peak metamorphic conditions.

The fact that early syn-orogenic granitoids were probably more competent than surrounding metamorphosed supracrustal rocks during regional compressional deformation under maximum metamorphic conditions (see Figure 3) may explain the relatively high number of gold mines and occurrences in and around metagranitoids in the lower greenstone zone (see Figure 2, in back pocket) and the prominence of carbonate alteration in these rocks (Parker 2000). Presumably, the early synorogenic granitoids were more likely to develop the fracture systems that formed conduits for mineralizing fluids generated by regional metamorphism and, subsequently, by intrusion of late synorogenic granitoids.

METAMORPHISM AND MAJOR STRUCTURES

This report focuses on the part of the deformational history that began with deposition of the Confederation assemblage in an extensional, presumably ensialic, tectonic setting; followed by horizontal compression and crustal thickening (orogenesis); and ending with exhumation of metamorphic rocks to the Earth's surface (see Figure 3). Hydrothermal metamorphism (alteration) associated with volcanism and synvolcanic felsic porphyries occurred at least twice, once during deposition of pre-Confederation Balmer, and a second time during deposition of the Confederation assemblage. This type of alteration may have occurred during other pre-Conferation assemblage volcanic events. The major unconformity at

the base of the Confederation assemblage (Sanborn-Barrie et al. 2000) may comprise, in part, fault scarps formed during extension of underlying crust. Extensional faults would be a likely source conduit for the fluids that caused the hydrothermal metamorphism (alteration) considered by Dubé et al. (2000) and Sanborn-Barrie et al. (2000) to be focussed along the unconformity at the Madsen Mine. These early relatively localized hydrothermal metamorphic events provide an explanation for the unusual aluminous mineral assemblages that formed in mafic metavolcanic rocks at Campbell/Goldcorp (Crocket et al. 1981; Penczak 1996) and Madsen (Lavigne et al. 1986) during the much younger, main phase of metamorphism.

There is abundant petrographic evidence indicating that main phase metamorphism overlapped in time and space with ductile deformation associated with crustal shortening and thickening (orogenesis). Though relatively rare in the samples used for this study, textural relations between porphyroblasts and planar/linear fabrics in thin section are consistent with peak metamorphic conditions outlasting the second phase of ductile deformation described by Dubé et al. (2000) and Sanborn-Barrie et al. (2000). Parker (2000) and Menard and Pattison (1998) came to similar conclusions. These observations are consistent with the fact that the metamorphic zones cut across the trends of the main foliation (S_2) in the west, east, and northeast segments of the greenstone belt (see Figure 2, in back pocket). Orogenesis provides a mechanism for transporting and burying volcanic and sedimentary rocks and related intrusions from at or near the Earth's surface down to the depths (pressures) and temperatures that produced the observed metamorphic mineral assemblages in these rocks (see Figure 3). The resulting thickening of the crust to thicknesses of 7 to 14 km greater than normal drives the uplift and erosion that exhumed the metamorphosed greenstone belt back to the surface.

Evidently, Sanborn-Barrie et al. (2000) are not convinced of the existence of the network of prominent linear deformation zones outlined by previous workers (Lavigne and Crocket 1983; Durocher and Hugon 1983; Andrews et al. 1986). The fact the metamorphic zones cut across these features as illustrated in Andrews et al. (1986) implies that the deformation zones would have formed before or during the time when peak metamorphic conditions prevailed. Relatively narrow high strain zones may have formed in the latter part of D_2 when the compressional strain regime changed from homogeneous to heterogeneous and deformation became concentrated in narrow zones. One of the proposed linear arrays of low grade metamorphic anomalies (Hoyles Bay, see Figure 2, in back pocket) coincides with the Post Narrows deformation zone. The northwest-striking "mine trend" which hosts the Cochenour past producing and Campbell and Goldcorp mines parallels the upper limit of the lower greenstone zone and links the anomalously high metamorphic gradients at Campbell/Goldcorp with the high metamorphic grade anomaly at Cochenour (see Figure 2, in back pocket). In these areas at least, it appears that a linear/planar feature localized fluid flow relatively late in the regional metamorphic history. Clearly, there is a spatial relation between metamorphic grade, major structures and gold.

METAMORPHIC HISTORY AND THE AGE OF THE AUSTIN "TUFF"

Sanborn-Barrie et al. (2002) conclude that zircons from a pebble metaconglomerate (Austin "Tuff" horizon) at the Madsen Mine (see Figure 2, in back pocket) previously interpreted as "hydrothermal zircons" (Sanborn-Barrie et al. 2001) are, in fact, dating the maximum age of deposition of the rock unit at 2700 ± 6 Ma. The authors suggested further that gold mineralization occurred after this date. Looking at the problem from the metamorphic perspective provided by this report (see Figure 3), it is more likely that these young ages are dating the metamorphism of the pebble metaconglomerate. Integration of metamorphic data and concepts with evidence of the history of deposition, deformation and plutonism in the Red Lake greenstone belt, indicates that the rock unit was buried to depths greater than 8 to 10 km at the time of intrusion of the Killala-Baird and Walsh batholiths (see path a, Figure 3). Cooling ages (Wright et al., 1991; Hanes and Archibald 1998) are consistent with the rocks being deeper than 5 km

2640 Ma ago. A special form of elevator tectonics is required to exhume the rocks beneath the pebble metaconglomerate to the surface, deposit a conglomerate, and rebury the rock units to depths consistent with its upper transition zone/lower amphibolite zone metamorphic assemblages, and subsequent cooling to 300° C approximately 60 million years later (see path b, Figure 3). Further work is required to evaluate the potential effects of regional metamorphism on detrital zircons in greenstone belts.

Metamorphism and Alteration

Mapping and chemical analysis of the products of alteration/hydrothermal metamorphism is widely used as an exploration tool for gold mineralization in greenstone belts. Metamorphic data and concepts provide constraints on the origin, timing, and distribution of altered rocks. Preliminary observations and comments are presented in this report. Further study of this issue is required.

There is general acceptance of the idea that the hydrothermal alteration event that transformed mafic and ultramafic metavolcanic rocks at Campbell/Goldcorp and Madsen into anomalously aluminous rocks occurred long before the metamorphism that caused the nucleation and growth of chloritoid, staurolite, andalusite, cordierite, and anthophyllite. Under metamorphic temperatures and pressures, these minerals replaced the chlorite and clay minerals produced by what was probably a syn-volcanic hydrothermal system on or near the sea floor.

Carbonate alteration is more problematic since the origin of the carbonate is uncertain. Rock units containing primary sedimentary or exhalative carbonate occur throughout the belt. The syn-volcanic hydrothermal alteration events noted above likely were associated with some carbonate deposition. Low grade regional metamorphism of mafic metavolcanic rocks in the presence of a CO₂-bearing hydrous fluid produces carbonate when calcium in igneous plagioclase and clinopyroxene combines with CO₂ in the fluid as basalt is transformed to greenstone. Alteration of mafic metamorphic rocks by CO₂-bearing hydrous fluids during or soon after the time when peak metamorphic conditions prevailed is common in greenstone belts. The timing of carbonate alteration of early synorogenic granitoids like the Dome Stock described by Parker (2000) may have occurred at this time in the metamorphic history of the Red Lake greenstone belt (see Figure 3). Discrimination between these various possible origins requires detailed mapping and petrographic analysis. Ten percent of the 598 samples used to create the metamorphic map are included in the rock association that comprises carbonate-rich rocks and their higher grade calc-silicate mineral-rich equivalents (see Rock Association 7, Figure 1, in back pocket). On the basis of petrographic observations alone, it appears that carbonate formed by primary, metamorphic, and late syn-metamorphic CO₂ alteration processes. In all cases, the carbonate has been recrystallized and variably deformed. These rocks show a range of metamorphic grade that is consistent with metamorphic zones based on other rock associations (see Figure 2, in back pocket). The highest grade diopside-grossularite assemblages correspond to the occurrences of "skarn" described by Parker (2000). Low grade, intensely deformed chlorite-carbonate phyllite in the Red Lake greenstone belt is essentially identical to the rocks found in gold-bearing deformation/alteration zones that occur in many greenstone belts. Regional petrography indicates that the belt-scale carbonate alteration zones mapped mainly on the basis of outcrop observations by Parker (2000) are not pervasive through all rock units at outcrop scale. That is, samples of rock associations adjacent to Rock Association 7 (see Table 1, Appendix 1) are not necessarily affected by the process. To some extent this reflects the variable reactivity of different rock types and the fact that alteration may be limited to narrow zones within any given outcrop. Petrography supports Parker's contention that most of the carbonate alteration is the same age or older than the relatively long period during which peak metamorphic conditions persisted (see Figure 3).

With respect to biotite alteration, it is interesting that the "biotite domains" outlined by Andrews et al. (Figure 7b, 1986) in the vicinity of East Bay on Red Lake and Balmer Lake occur upgrate of the biotite isograd (see Figure 2, in back pocket). The biotite observed in carbonate alteration zones associated with gold mineralization (Andrews et al. 1986) may be the higher grade metamorphic equivalent of the "sericite"-chlorite carbonate alteration commonly associated with gold mineralization. The question is: is the biotite a product of metamorphism of pre-existing chlorite-"sericite" alteration or did it form at the same time as the latter but at higher temperatures? Clearly, more work is needed to determine the origin, timing, and distribution of all types of alteration in the belt.

Metamorphism and Gold Exploration

Two zone boundaries and the metamorphic anomalies that occur within zones outlined on the new metamorphic map of the Red Lake greenstone belt (see Figure 2, in back pocket) are prospective for gold. Sample density controlling the location of zone boundaries and the shape and size of metamorphic anomalies, varies considerably across the map area (see Figure 2, in back pocket). More sampling and further petrography is required to verify and refine the following observations and comments.

LOWER/UPPER GREENSTONE ZONE BOUNDARY (BIOTITE ISOGRAD)

Regional petrographic work in the Eastern Goldfields, Western Australia (Mikucki and Roberts 2003; Hall 1998) and in the Timmins area, Abitibi greenstone belt (Thompson 2002b) indicates that major gold mines occur on or near the boundary between the upper and lower greenstone zone (upper and lower greenschist facies). In both terranes, the boundary corresponds to the biotite isograd as defined in quartzofeldspathic rocks. The reconnaissance petrographic data presented in this report (see Figures 1 and 2 in back pocket; see Tables 1 and 2, in Appendix 1) indicate that of 22 current and past producers in the Red Lake greenstone belt, 12 occur within 900 m of the biotite isograd (see Figure 2, in back pocket) which is the boundary between the lower and upper greenstone zones. In the absence of knowledge of the dip of the metamorphic zone boundary, true distance is not known. Of these, the two most productive mines, Campbell and Goldcorp are less than 200 m from the isograd. Improving the constraints on the biotite isograd is a priority for future work. This first attempt to map the feature, however, does indicate that the biotite isograd is a valid gold exploration target in the Red Lake greenstone belt.

TRANSITION ZONE (GREENSCHIST/AMPHIBOLITE FACIES BOUNDARY)

The boundary between the greenschist and amphibolite facies occurs in the upper part of the transition zone as defined in metamorphosed basalt/gabbro (see Figure 1 and yellow zone on Figure 2, in back pocket). Four of the past and current producers in the Red Lake greenstone belt occur in or within 200 m of the transition zone as defined in metabasites. The Madsen No. 1 and Red Summit mines occur in lower amphibolite zone rocks close to the boundary with the transition zone. The Gold Corp-Red Lake Mine is located on the low-grade side of the lower boundary of the zone. The Madsen ore zones 1 to 8 occur in the transition zone (see Figure 2, in back pocket). In the Yellowknife Greenstone Belt (Slave Province, northwestern Canadian Shield), the Con-Giant gold deposit straddles the lower boundary of the transition zone (Thompson, in preparation). In the Eastern Goldfields of Western Australia, several important gold mines are located near a blue-green hornblende isograd (Mikucki and Roberts 2003) that

is analogous to the lower grade part of the transition zone in the Red Lake greenstone belt. Once again, keeping in mind the variable quality of control on the location of the transition zone in Figure 2, there is enough evidence from this study to support the idea that this metamorphic zone is prospective for gold. Of particular interest is the new evidence that, east of Madsen, the boundary between the greenschist and amphibolite facies which falls in the upper part of the transition zone (see Figure 1, in back pocket) does not trend to the southeast as indicated by Andrews et al. (1986). Rather, the isograd continues northeast and north of Madsen before bending to the northwest about 2000 m southeast of the Goldcorp-Red Lake Mine (see Figure 2, in back pocket). This new segment of the transition zone is prospective for gold. Given that major structural zones like the "mine trend" that links Campbell/Goldcorp to Cochenour are prospective for gold, the intersections of deformation zones with either the transition zone or the boundary between the lower and upper greenstone zones (biotite isograd) also merit further attention.

METAMORPHIC ANOMALIES

Isolated occurrences of low metamorphic grade rocks in higher metamorphic grade zones (cold spots), of higher metamorphic grade rocks in low grade zones (hot spots), and of steep metamorphic gradients (closely spaced metamorphic zone boundaries) (see Figure 2, in back pocket) are relevant to gold exploration models because they may correspond to zones affected by focussed flow of heat and hydrothermal fluids. "Hot spots" may be related to buried plutons; structural conduits such as intersecting deformation zones or fold hinges; or litho-structural conduits that form at or near contacts between rock units of differing competency. Relatively high fluid flow rates and steep temperature gradients associated with such features are conducive to formation of gold mineralization. The cluster of gold deposits around the high grade anomaly west of Cochenour (see Figure 2 in back pocket) should be re-evaluated with this concept in mind. High metamorphic grade anomalies should be targeted for intrusive-related and deformation zone-hosted gold deposits.

"Cold spots" develop where the temperature and/or CO₂ content of the fluid are not in equilibrium with the mineral assemblages in adjacent greenstone, transition or amphibolite zone rocks. Commonly, low grade metamorphic anomalies (carbonate-chlorite, carbonate-chlorite-white mica) are attributed to rock-fluid interactions that occur along structural conduits after the peak of metamorphism, during cooling and exhumation. However, the same "low grade" mineral assemblages can form under peak metamorphic conditions, if the proportion of CO₂ in the hot hydrothermal fluid is high enough. The latter explanation is more likely in geological settings, where hydrothermal fluid production is related to contact or regional metamorphism or to synorogenic intrusions themselves. Low grade metamorphic anomalies such as those east and north of Balmer Lake, in the south part of Heyson township and northwest and north of Madsen (see Figure 2 in back pocket), therefore, are also prospective for both intrusive- and deformation zone-related gold deposits.

In the absence of faults extending parallel to metamorphic zonation, closely spaced metamorphic zone boundaries are the products of steep temperature gradients. Rapid changes in temperature and high rates of fluid flow anticipated in such an environment could have significant impact on the composition of gold mineralizing fluids. In addition to the steep metamorphic gradients associated with metamorphic anomalies, there are segments of the regional metamorphic zonation characterized by closely spaced metamorphic zone boundaries (see Figure 2 in back pocket). Allowing for the fact that the degree of control on the locations of the boundaries is variable, the association of the Campbell and Goldcorp mines with closely spaced isograds indicates further exploration of other areas with steep metamorphic gradients is worth doing. Of course, if the biotite isograd (lower/upper greenstone zone boundary) and the transition from greenstone to amphibolite zones are prospective, areas where these features are close together are of high interest.

LOW GRADE, LOW PRESSURE METAMORPHISM AND GOLD

The Red Lake greenstone belt is another example of the apparent link between low grade, low pressure metamorphism and gold deposits. Citing Hodgson et al. (1993) and Phillips et al. (1997), Loucks and Mavrogenes (1999) suggested that ninety percent of the gold mined from metamorphic terranes around the world was deposited at temperatures and pressures in the range 250–450° C and 1–3 kilobars. That is, deposition occurred under low pressure subgreenschist to greenschist facies metamorphism. The high value of ninety percent likely includes gold deposits formed at or near the Earth's surface during pre-metamorphic synvolcanic magmatic and exhalative processes. Referring to this set of P-T conditions as the "gold deposition zone" Thompson (1999; in press; 2002b) has explored the potential significance of this idea within a dynamic geological setting represented schematically by depth-time diagrams similar to Figure 3. By definition, low pressure type metamorphic terranes (andalusite at medium grade, Miyashiro, 1961) are less deeply eroded than medium pressure terranes (kyanite stable at medium grade). Hence gold deposits that formed at relatively shallow depths in the crust during orogenesis are more likely to be preserved in low pressure metamorphic terranes such as the Red Lake greenstone belt and others exposed in the Archean Superior and Slave provinces of the Canadian Shield and Eastern Goldfields of Western Australia. Furthermore, the high average geothermal gradients (40–75° C/km) to depths of 10–15 km that are characteristic of low pressure regional metamorphic terranes create a relatively thick gold deposition zone in the crust (see Figure 3). Therefore, in a low pressure metamorphic setting such as that preserved in the Red Lake greenstone belt, rocks that end up at or within a kilometre or two of the Earth's surface likely spent tens of millions of years within the P-T range conducive to gold deposition.

Recommendations for Future Work

Based entirely on thin sections obtained from the archives of the Ontario Geological Survey and the Geological Survey of Canada, this study is the first step toward a comprehensive metamorphic framework for gold exploration in the Red Lake greenstone belt. This study builds on and enhances the important contributions of previous workers. Further sampling and petrography are required to improve the definition of metamorphic zones outlined in this report and to further test the utility of metamorphic data and concepts as gold exploration tools. Below is a list of outstanding problems that need to be addressed.

- Use sampling and petrography to improve and refine definition of the lower/upper greenstone zone boundary (biotite isograd) in the eastern half of the Red Lake greenstone belt, with emphasis on the area northwest and southwest of Cochenour that lies between the three high grade metamorphic anomalies and in the area south and southeast of Campbell/Goldcorp.
- Investigate further the origins of high and low grade metamorphic anomalies and their relation in time and space to gold mineralization.
- Improve definition of the transition zone between the upper greenstone and amphibolite zones along the segment between the Madsen and Campbell-Goldcorp mines.
- Integrate the new metamorphic data and concepts presented here with other data sets with the objective of defining new multi-parameter gold exploration targets.

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Appendix 1

Table 1

Comprehensive data table, showing sample number, location (UTM datum NAD 1927), metamorphic grade, deformation and alteration of 781 thin sections examined.

Table 2

List of 598 samples depicted on Figure 2 (*Metamorphic Map, Red Lake Greenstone Belt*, see back pocket), showing sample number, location (UTM datum NAD 1927), and metamorphic grade.

Table 1. Sample number, location (UTM datum NAD 1927), grade, deformation, alteration, 781 thin sections. See Figure 1 and 2 in back pocket for legend for rock association and metamorphic grade.

Reference Number	Sample Number	UTM Zone 15		Rock Association	Metamorphic Grade	Deformation	Alteration		
		Easting	Northing				type	intensity	timing
1	76-16-29	438900	5662140	2	22	w			
2	76-16-36	439245	5662525	1	13	m			
3	76-16-39	439495	5662760	2	22	m			
4	76-16-41	439660	5662975	7	72	m			
5	76-16-49	440830	5662125	1	11	m			
6	76-16-54	440850	5661965	2	22	n			
7	76-16-65	445000	5664735	2	22	m			
8	76-16-68	444885	5665065	5	52	n			
9	76-16-75	445000	5666000	2	22	m			
10	76-16-98	437545	5662150	2	21	m			
11	76-16-124	442705	5663770	1	12	n			
12	76-16-126	442670	5663865	1	11	w			
13	76-16-137	443455	5663890	6	62	w			
14	76-16-209	437105	5662745	1	12	w			
15	76-16-212	440830	5664830	1	11	n			
16	76-16-218	439885	5665060	2	22	w			
17	76-16-220	440305	5665070	2	22	n			
18	76-16-222	440450	5665030	5	52	n			
19	76-16-233	445930	5664685	4	42	m			
20	76-16-236	446005	5664440	7	72	m			
21	76-16-238	446165	5664665	2	21	m			
22	76-16-239	446185	5664570	2	22	m			
23	76-16-240	446300	5664840	5	52	m			
24	76-16-242	446350	5664885	4	42	m			
25	76-16-250	446525	5667270	4	42	i			
26	76-16-255	446265	5665345	1	11	n			
27	76-16-257	446210	5665310	1	11	n			
28	76-16-259	446290	5665230	1	12	n			
29	76-16-259B	446290	5665230	1	12	n			
30	76-16-262	438195	5663565	2	22	m			
31	76-16-272	437150	5664485	2	22	m			
32	76-16-278	437710	5665150	2	22	m			
33	76-16-281	437175	5664850	6	62	m			
34	76-16-284	439355	5664890	2	22	m			
35	76-16-286	439235	5665485	4	42	m			
36	76-16-287	439290	5665525	4	42	m			
37	76-16-293	438610	5666335	4	42	m			
38	76-16-294	438060	5666725	2	22	m			
39	76-16-297	437445	5667300	6	62	m			
40	76-16-319	440610	5664350	1	13	n			
41	76-16-365	439075	5664435	6	62	n			
42	76-16-401	438615	5667415	2	22	n			
43	76-16-402	438550	5667455	2	22	m			
44	76-16-408	441000	5663920	2	22	w			
45	76-16-603	437600	5670000	6	62	m			
46	76-16-609	446590	5669130	2	22	m			
47	76-16-610	446685	5669475	6	62	m			

Reference Number	Sample Number	UTM Zone 15		Rock Association	Metamorphic Grade	Deformation	Alteration		
		Easting	Northing				type	intensity	timing
48	76-16-611	446685	5669930	6	62	m			
49	76-16-615	445370	5664520	3	32	n			
50	76-16-616	445370	5664520	3	32	n			
51	76-16-617	445370	5664520	3	32	n			
52	76-16-618	445370	5664520	3	32	w			
53	76-16-618B	445370	5664520	3	32	w			
54	76-16-619	445370	5664520	3	32	n			
55	76-16-620	445370	5664520	3	32	n			
56	76-16-621	445370	5664520	3	32	n			
57	76-16-637	443275	5662105	2	21	m			
58	76-16-638	443245	5662060	7	71	m			
59	76-16-654	439555	5667505	2	22	m			
60	76-16-656	439665	5667705	2	22	m			
61	76-16-659	440210	5667950	2	22	m			
62	76-16-676	442460	5662045	1	11	n			
63	76-16-680	443290	5665590	1	12	n			
64	76-16-683	446420	5666550	1	12	n			
65	76-16-693	445430	5663645	2	22	m			
66	76-16-696	446000	5663635	3	31	n			
67	76-16-723	440070	5665910	4	42	i			
68	76-16-730	441090	5667275	4	42	i			
69	76-16-746	440260	5669115	1	13	m			
70	76-16-771	445070	5661910	3	31	n			
71	76-16-803	445925	5664940	1	12	w	3	w	ll
72	76-16-817	444785	5661845	1	11	n			
73	76-16-821	446465	5663950	2	21	w			
74	76-16-822	446600	5663935	2	22	w			
75	76-16-825	443910	5662045	7	71	i			
76	76-16-827	447045	5665095	2	22	m			
77	76-16-833	445725	5667880	1	12	n			
78	76-16-911	443550	5662575	4	42	m			
79	76-16-1002	446850	5665450	2	21	m			
80	76-16-1004	446965	5665580	2	22	m			
81	76-16-1005	446970	5665585	2	22	m			
82	76-16-1006	447365	5666115	2	22	m			
83	76-16-1007	447455	5666120	2	22	m			
84	76-16-1008	447525	5666115	4	42	m			
85	76-16-1009	447525	5666080	5	52	w			
86	76-16-1011	451130	5665665	1	13	n			
87	76-16-1014	451920	5664990	7	72	w			
88	76-16-1015	451885	5664615	1	11	n			
89	76-16-1017	454035	5669475	1	13	w			
90	76-16-1022	447795	5666165	2	22	m			
91	76-16-1023	447720	5666285	5	52	n			
92	76-16-1024	447725	5666345	2	22	m			
93	76-16-1026	448245	5666250	1	12	w			
94	76-16-1027	448740	5666190	1	11	w			
95	76-16-1029	449405	5656595	5	59	n			
96	76-16-1031	453375	5657405	1	11	n			
97	76-16-1035	453605	5657585	7	72	m			
98	76-16-1036	453885	5658730	3	32	m			

Reference Number	Sample Number	UTM Zone 15		Rock Association	Metamorphic Grade	Deformation	Alteration		
		Easting	Northing				type	intensity	timing
99	76-16-1041	455150	5668225	8	80	n			
100	76-16-1047	455540	5667785	6	62	n			
101	76-16-1060	447120	5664895	2	22	m			
102	76-16-1062	447205	5665270	2	29	m			
103	76-16-1063	447195	5665245	2	22	m			
104	76-16-1065	449875	5665945	6	62	w			
105	76-16-1069	447895	5668905	7	73	m			
106	76-16-1070	448235	5669695	7	73	n			
107	76-16-1071	448350	5670160	2	22	m			
108	76-16-1073	453620	5663955	7	73	m			
109	76-16-1078	452395	5666135	2	22	m			
110	76-16-1085	453635	5661495	1	13	m			
111	76-16-1086	453645	5661575	5	52	n			
112	76-16-1087	453605	5661895	1	13	n			
113	76-16-1091	453590	5660650	1	13	m			
114	76-16-1095	447530	5663800	2	22	m			
115	76-16-1098	447740	5663925	1	12	w			
116	76-16-1101	449705	5664040	1	13	w			
117	76-16-1107	449285	5664150	3	32	n			
118	76-16-1128	454955	5669145	8	80	n			
119	76-16-1138	450915	5663270	2	22	w			
120	76-16-1144	447905	5667730	2	22	w			
121	76-16-1145	447040	5668150	2	22	w			
122	76-16-1153	453210	5663265	1	13	w			
123	76-16-1154	453350	5663305	1	13	n			
124	76-16-1175	454285	5664995	1	13	m			
125	76-16-1181	455735	5663400	8	80	n			
126	76-16-1187	448145	5667005	2	22	m			
127	76-16-1191	447735	5666790	3	32	n			
128	76-16-1193	448065	5666735	5	52	w			
129	76-16-1194	449240	5666135	1	12	w			
130	76-16-1202	448345	5664220	7	72	w			
131	76-16-1203	448365	5664055	1	12	w			
132	76-16-1206	455895	5657335	1	12	w			
133	76-16-1207	455900	5657335	1	12	w			
134	76-16-1210	448275	5663740	7	72	m			
135	76-16-1211	448255	5663625	3	32	n			
136	76-16-1213	448035	5663410	1	12	m			
137	76-16-1215	450245	5656165	1	12	n			
138	76-16-1218	451220	5655505	1	12	w			
139	76-16-1219	451105	5655430	1	11	n			
140	76-16-1226	450310	5653735	7	72	w			
141	76-16-1233	447245	5654710	7	71	w			
142	76-16-1234	447245	5654710	7	71	n			
143	76-16-1235	453875	5658590	1	11	w			
144	76-16-1241	455090	5660345	1	12	n			
145	76-16-1242	454960	5660190	1	13	w			
146	76-16-1244	453090	5660175	1	12	n			
147	76-16-1252	449945	5657630	2	22	w			
148	76-16-1253	450810	5657770	4	43	w			
149	76-16-1307	449345	5666320	2	22	m			

Reference Number	Sample Number	UTM Zone 15		Rock Association	Metamorphic Grade	Deformation	Alteration		
		Easting	Northing				type	intensity	timing
150	76-16-1314	449645	5655990	2	21	w			
151	76-16-1323	449360	5653935	2	22	m			
152	76-16-1328	453305	5659445	1	13	m			
153	76-16-1337	455110	5653365	1	13	w			
154	76-16-1345	453855	5652965	1	12	m			
155	76-16-1353	452880	5657395	1	12	n			
156	76-16-1379	451225	5667800	1	13	m			
157	76-16-1385	449245	5658040	1	13	m			
158	76-16-1395	448170	5656560	4	42	m			
159	76-16-1403	448630	5665200	5	52	w			
160	76-16-1408	451670	5654815	1	13	m			
161	76-16-1415	450625	5657815	1	13	w			
162	76-16-1424	448325	5657765	3	31	n			
163	76-16-1426	448610	5657180	7	72	m			
164	76-16-1431	449040	5657625	1	11	w			
165	76-16-1432	449100	5658215	2	22	n			
166	76-16-1437	448485	5656935	2	21	w			
167	76-16-1438	448475	5656670	7	72	m			
168	76-16-1446	447290	5655430	7	71	n	3	m	II
169	76-16-1448	447505	5655430	2	21	n			
170	76-16-1458	446765	5652765	1	11	m			
171	76-16-1477	448005	5656500	1	11	m			
172	76-16-1478	447030	5656190	2	21	i			
173	76-16-1485	454890	5652320	1	12	m			
174	76-16-1508	449510	5656960	1	12	w			
175	76-16-1604A	446870	5664995	1	12	n			
176	76-16-1638	446980	5665565	2	29	i			
177	79-PR-01	440685	5649340	1	13	w			
178	79-PR-02	441720	5649105	2	22	m			
179	79-PR-04	440830	5648910	2	22	m			
180	79-PR-06	440710	5649480	1	11	n			
181	79-PR-07	441090	5649315	2	22	m			
182	79-PR-11	439165	5647120	2	22	m			
183	79-PR-13	438805	5647000	2	22	m			
184	79-PR-15	440110	5651320	6	62	i			
185	79-PR-19	439485	5646820	2	22	m			
186	79-PR-22	439890	5646235	7	73	m			
187	79-PR-24	440810	5646480	1	13	m			
188	79-PR-25	440115	5646255	1	13	w			
189	79-PR-28	441300	5648510	2	22	m			
190	79-PR-29A	441665	5648420	2	22	m			
191	79-PR-30	437370	5648000	7	72	m			
192	79-PR-31	437645	5648010	1	13	m			
193	79-PR-35	437240	5647290	6	62	m			
194	79-PR-37	445620	5643240	2	22	w			
195	79-PR-38	445419	5643220	1	13	i			
196	79-PR-46	438880	5642885	2	21	m			
197	79-PR-52	439560	5648890	2	22	w			
198	79-PR-54	439840	5649195	1	11	n			
199	79-PR-55	440325	5649790	2	22	m			
200	79-PR-56	440410	5649885	2	22	i			

Reference Number	Sample Number	UTM Zone 15		Rock Association	Metamorphic Grade	Deformation	Alteration		
		Easting	Northing				type	intensity	timing
201	79-PR-58	440680	5650195	2	22	m			
202	79-PR-59	440910	5650470	2	29	m			
203	79-PR-63	438420	5643000	7	72	i			
204	79-PR-64	438390	5643620	2	22	m			
205	79-PR-65	438275	5643340	1	13	w			
206	79-PR-69	442955	5642815	7	73	m			
207	79-PR-70	442915	5642965	2	22	m			
208	79-PR-72	442950	5643125	1	11	n			
209	79-PR-77	442815	5648215	7	73	m			
210	79-PR-79	442000	5648145	2	22	w			
211	79-PR-83	437020	5645090	6	62	w			
212	79-PR-87	444490	5648970	1	11	n			
213	79-PR-88	444495	5649220	2	22	w			
214	79-PR-89	444540	5649165	2	22	w			
215	79-PR-91	440475	5648580	2	22	m			
216	79-PR-93	440710	5648380	1	12	n			
217	79-PR-94	440845	5647870	2	22	m			
218	79-PR-112	437845	5646775	2	22	m			
219	79-PR-117	437620	5645845	6	62	n			
220	79-PR-137A	438755	5649020	1	12	n			
221	79-PR-140A	439250	5648630	1	12	n			
222	79-PR-140B	439250	5648630	2	22	n			
223	79-PR-149	440820	5647430	2	22	n			
224	79-PR-161	437695	5648790	1	12	n			
225	79-PR-170	438225	5646795	2	22	m			
226	79-PR-172	438265	5646580	2	22	m			
227	98JRP0007	414961	5650574	4	43	m	1	i	i
228	98JRP0007B	414961	5650574	4	43	m	1	i	i
229	98JRP0007D	414961	5650574	5	52	i			
230	98JRP0007E	414961	5650574	5	52				
231	98JRP0007G	414961	5650574	4	43		1	i	i
232	98JRP0007K	414961	5650574	9	99				
233	98JRP0007L	414961	5650574	9	99				
234	98JRP0007N	414961	5650574	1	13				
235	98JRP0007Q	414961	5650574	1	13				
236	98JRP0007Y	414961	5650574	1	13				
237	98JRP0011A	415195	5650607	1	13	m			
238	98JRP0011J	415195	5650607	1	13				
239	98JRP0011N	415195	5650607	1	13				
240	98JRP0011Q	415195	5650607	4	43		1	i	i
241	98JRP0011U	415195	5650607	4	43		1	i	i
242	98JRP0011V	415195	5650607	4	43				
243	98JRP0027B	444450	5649131	2	22				
244	98JRP0037B	440373	5649758	2	22				
245	98JRP0042B	440785	5650285	2	22				
246	98JRP0053B	440184	5648480	2	22				
247	98JRP0057B	440538	5648092	2	22	m			
248	98JRP0074B	449533	5647186	2	22				
249	98JRP0075B	452948	5647040	2	22				
250	98JRP0078B	411602	5658849	2	22				
251	98JRP0084B	413623	5658122	2	21				

Reference Number	Sample Number	UTM Zone 15		Rock Association	Metamorphic Grade	Deformation	Alteration		
		Easting	Northing				type	intensity	timing
252	98JRP0086B	413237	5657627	2	22				
253	98JRP0087B	413769	5656655	2	21				
254	98JRP0089B	416547	5654893	2	22	i			
255	98JRP0090B	416817	5654643	2	22				
257	98JRP0111B	445513	5642805	2	22				
278	99JRP9188C	444632	5646161	2	22				
279	99JRP9192B	444235	5646901	2	22				
280	99JRP9194B	444081	5647166	2	22				
281	99JRP9195B	444057	5647231	2	22	w			
282	99JRP9196C	444010	5647316	2	22				
283	99JRP9198B	443838	5647636	1	13				
284	99JRP9279C	415899	5648248	7	73		3	i	u
285	99JRP9294B	416259	5650098	2	22				
286	99JRP9295B	415664	5649375	1	11				
287	99JRP9298B	415161	5649249	1	11				
288	99JRP9306B	414837	5650034	2	22		1	w	i
289	99JRP9315C	414334	5650570	1	13				
290	99JRP9320C	415378	5650437	1	12				
291	99JRP9321B	415312	5650452	1	11				
292	99JRP9352B	415166	5650288	1	12				
293	99JRP9356C	415465	5650300	1	11				
294	99JRP9363B	415458	5649640	4	43				
295	99JRP9366B	415185	5649640	1	12				
296	99JRP9371B	435453	5645793	2	22	i			
297	99JRP9371D	435453	5645793	2	22	m			
298	99JRP9395B	413701	5651372	2	22				
299	99JRP9399B	414969	5650571	2	21	m			
300	99JRP9399C	414969	5650571	1	11	m			
301	99JRP9411B	426527	5655828	1	11				
302	99JRP9417B	429068	5655169	7	71	i	3	i	III
303	99JRP9429B	423779	5654710	1	12				
304	99JRP9437B	423267	5653189	2	22				
305	99JRP9444B	423423	5654492	1	13				
306	99JRP9444D	423423	5654492	2	22	m			
307	99JRP9480B	426970	5654040	1	13				
308	99JRP9482B	427000	5654353	1	13				
309	99JRP9484C	426997	5654171	1	13				
310	99JRP9485C	427088	5654253	1	22		2	m	I
311	99JRP9505C	423870	5653493	7	73		3	i	I
312	99JRP9522D	413525	5656639	1	12				
313	99JRP9526B	426201	5656094	1	11				
314	99JRP9537B	424696	5657314	2	22				
315	99JRP9537F	424696	5657314	6	62		23	m	III
316	99JRP9551B	421392	5657300	6	61		12	w	III
317	99JRP9556C	426037	5656411	1	11				
318	99JRP9557B	426081	5656358	1	11				
319	99JRP9558B	426263	5656367	1	11				
320	99JRP9564B	425358	5656604	1	11				
321	99JRP9584C	420590	5657851	1	12				
322	99JRP9586B	420525	5657947	1	12		23	w	II
323	99JRP9587B	420417	5657940	1	11		2	m	i

Reference Number	Sample Number	UTM Zone 15		Rock Association	Metamorphic Grade	Deformation	Alteration		
		Easting	Northing				type	intensity	timing
324	99JRP9592C	418976	5657592	1	11	i			
325	99JRP9593D	419328	5657523	2	29		4	w	I
326	99JRP9611	421526	5657398	2	22		2	w	II
327	99JRP9613B	419902	5657848	2	22				
328	99JRP9621B	419847	5657956	2	22	m	2	w	II
329	99JRP9622B	419814	5657878	2	22				
330	97JRP9624B	419857	5658073	6	62				
331	99JRP9627B	419317	5658439	1	13				
332	99JRP9627D	419317	5658439	4	43		12	m	III
333	99JRP9627E	419317	5658439	7	71				
334	99JRP9629B	419808	5658244	1	11				
335	99JRP9629D	419808	5658244	2	29				
336	99JRP9629F	419808	5658244	2	22				
337	99JRP9629L	419808	5658244	7	72				
338	99JRP9634B	420618	5657441	2	29	m			
339	99JRP9642B	419519	5655807	2	21				
340	99JRP9642D	419519	5655807	3	31				
341	99JRP9644B	421193	5656240	2	21				
342	99JRP9649C	421078	5656153	2	21				
343	99JRP9650B	421029	5656060	2	21				
344	99JRP9663B	430205	5658252	2	22	m			
345	99JRP9669B	431180	5657897	1	12				
346	99JRP9671E	431309	5657904	1	13				
347	99JRP9682B	414487	5653964	7	71	m	3	m	II
348	99JRP9689B	417358	5654180	2	29	m			
349	99JRP9689D	417358	5654180	2	29				
350	99JRP9690B	417521	5654290	6	62		2	m	II
351	99JRP9696D	433567	5658820	2	22				
352	99JRP9696F	433567	5658820	2	22				
353	99JRP9700B	433597	5658956	2	22				
354	99JRP9701B	437048	5661410	2	22				
355	99JRP9702C	436531	5660415	2	22				
356	99JRP9708B	411655	5656013	2	22	m			
357	99JRP9736B	412782	5655025	1	12	m			
358	00JRP8020B	435903	5651021	7	71	w	3	i	u
359	00JRP8028B	436339	5650937	7	72	i	23	i	u
360	00JRP8035B	444825	5657929	7	71	i	2	i	u
361	00JRP8036B	444864	5658116	6	62				
362	00JRP8038B	444952	5658086	1	11	w	12	i	u
363	00JRP8058B	445293	5659748	7	71	i	13	i	u
364	00JRP8060B	445338	5659799	2	21	i	4	w	I
365	00JRP8060D	445338	5659799	7	71		3	m	u
366	00JRP8064B	445036	5660224	1	11		13	i	II
367	00JRP8068B	444538	5660423	7	71	m	13	i	u
368	00JRP8071B	443640	5658461	7	71	m	13	i	u
369	00JRP8072B	443703	5658411	2	29				
370	00JRP8072D	443703	5658411	2	21	m	245	i	u
371	00JRP8072F	443703	5658411	2	21		245	i	u
372	00JRP8072H	443703	5658411	7	71	m	123	i	u
373	00JRP8073B	443737	5658394	7	71	m	123	i	u
374	00JRP8073D	443737	5658394	2	21		25	i	u

Reference Number	Sample Number	UTM Zone 15		Rock Association	Metamorphic Grade	Deformation	Alteration		
		Easting	Northing				type	intensity	timing
375	00JRP8076B	443890	5658513	7	71		235	i	u
376	00JRP8077B	444017	5658554	7	71	i	125	i	u
377	00JRP8092B	444495	5661078	1	12				
378	00JRP8093B	446297	5652424	1	13				
379	00JRP8097B	446435	5652858	1	12				
380	00JRP8105B	446420	5653117	2	22	i			
381	00JRP8107B	446145	5653457	1	12	m			
382	00JRP8108B	445996	5653009	2	22				
383	00JRP8108D	445912	5653113	2	22				
384	00JRP8111B	434029	5647419	1	12	i			
385	00JRP8135B	445764	5661019	2	29	m	4	w	i
386	00JRP8157B	447723	5663943	1	12	m			
387	00JRP8164B	446602	5662214	7	72		13	i	u
388	00JRP8168B	447010	5659422	7	72				
389	00JRP8174B	448844	5660444	2	22	i	123	m	ll
390	00JRP8176B	449365	5660655	1	13				
391	00JRP8182B	450871	5663043	2	22				
392	00JRP8199A	455412	5659897	1	13				
393	00JRP8199B	455412	5659897	1	13				
394	00JRP8201B	456208	5659938	8	80				
395	00JRP8202B	456763	5661908	8	80				
396	00JRP8204B	456763	5662980	8	80				
397	00JRP8205B	451113	5658445	1	13				
398	00JRP8213B	452055	5659175	4	43				
399	00JRP8214B	452114	5659125	4	43				
400	00JRP8214C	452114	5659125	4	43	i			
401	00JRP8218B	451356	5665712	1	13	m			
402	00JRP8220B	451329	5665845	3	32				
403	00JRP8220C	451329	5665845	7	73		34	i	l
404	00JRP8220D	451329	5665845	7	73		3	i	l
405	00JRP8227B	455324	5670180	4	43	m	1	i	l
406	00JRP8227C	455324	5670180	5	52				
407	00JRP8230A	456049	5671017	5	52				
408	00JRP8232A	450972	5654802	2	22				
409	00JRP8232B	450972	5654802	2	22				
410	00JRP8243B	452613	5654126	1	13	i			
411	00JRP8246B	445264	5654297	1	11		123	m	u
412	00JRP8247B	445481	5654269	5	22	m			
413	00JRP8248B	446417	5654392	1	11		13	m	u
414	00JRP8249B	449363	5663965	7	79	m	3	i	u
415	00JRP8250B	449426	5664088	5	52				
416	00JRP8251B	449552	5664091	7	72		3	i	l
417	00JRP8252B	449319	5663952	7	72				
418	00JRP8252D	449319	5663952	7	72		3	m	u
419	00JRP8256B	447173	5664982	7	72	m	23	m	u
420	00JRP8257B	446177	5664632	2	21				
421	00JRP8259B	445456	5664771	7	72		23	m	u
422	00JRP8276B	441798	5661042	1	11				
423	00JRP8284B	440865	5660402	2	21	m			
424	00JRP8286B	440491	5660529	7	71	m	3	i	u
425	00JRP8287B	440425	5660628	5	22	i	13	i	u

Reference Number	Sample Number	UTM Zone 15		Rock Association	Metamorphic Grade	Deformation	Alteration		
		Easting	Northing				type	intensity	timing
426	00JRP8288B	439930	5660316	2	21	i	13	i	u
427	00JRP8291B	441509	5660379	2	21				
428	00JRP8291D	441509	5660379	2	22	i	13	i	u
429	00JRP8292B	441605	5660289	2	21				
430	00JRP8306B	447995	5653149	2	21				
431	00JRP8307B	447854	5652906	1	12				
432	00JRP8308B	447784	5652787	1	13				
433	00JRP8320C	442057	5660187	7	72		3	i	u
434	00JRP8322C	442274	5660276	2	29				
435	00JRP8322F	442274	5660276	2	22				
436	00JRP8334B	443576	5659687	2	29				
437	00JRP8346B	443391	5658751	4	43		1	m	l
438	00JRP8348B	443088	5658674	4	43		5	m	u
439	00JRP8355B	446171	5653635	7	71		13	m	u
440	00JRP8358B	442883	5654250	6	29	i			
441	00JRP8358D	442883	5654250	6	61	i	123	w	u
442	00JRP8370B	433882	5655139	7	73		3	i	u
443	00JRP8371B	434027	5655246	7	73		3	i	u
444	00JRP8372B	434146	5654572	6	62				
445	00JRP8376B	428911	5653504	2	22				
446	00JRP8378	428179	5653689	7	72		3	i	u
447	00JRP8379	430848	5653410	1	11		cb cht		
448	00JRP8391B	427580	5653583	8	80				
449	00JRP8392B	428113	5653688	1	12		3	m	u
450	00JRP8392C	428113	5653688	1	12		3	i	u
451	00JRP8397B	428919	5653582	7	72		3	i	u
452	00JRP8401B	421156	5652913	8	80				
453	00JRP8402	419694	5653256	1	12		2	w	l
454	00JRP8406C	422322	5655459	5	52				
455	00JRP8408B	421083	5653316	7	73		3	i	u
456	00JRP8417B	438119	5663016	2	22				
457	00JRP8426B	446942	5654463	1	11	m			
458	00JRP8427D	415310	5650466	3	32				
459	00JRP8427F	415310	5650466	3	32				
460	00JRP8427H	415310	5650466	3	32				
461	00JRP8427J	415310	5650466	1	12				
462	00JRP8428B	415378	5650637	3	32				
463	00JRP8428D	415378	5650637	3	32				
464	00JRP8429B	414844	5651034	3	32	i			
465	00JRP8429D	414844	5651034	3	32				
466	00JRP8429F	414844	5651034	1	12				
467	00JRP8429H	414844	5651034	1	12				
468	00JRP8431	447275	5655352	7	71	m	13	i	u
469	00JRP8431B	447275	5655352	7	71		123	i	u
470	00JRP8431D	447275	5655352	7	71		23	i	u
471	00JRP8432B	443567	5656683	4	41		1	m	l
472	00JRP8432D	443567	5656683	4	41		14	m	l
473	00JRP8434B	443648	5657384	2	21				
474	00JRP8434C	443648	5657384	2	29				
475	00JRP8455B	448057	5657348	2	21				
476	00JRP8455D	448057	5657348	2	21				

Reference Number	Sample Number	UTM Zone 15		Rock Association	Metamorphic Grade	Deformation	Alteration		
		Easting	Northing				type	intensity	timing
477	00JRP8455F	448057	5657348	2	22	m			
478	00JRP8455H	448057	5657348	1	11				
479	00JRP8455J	448057	5657348	1	11				
480	00JRP8455L	448057	5657348	1	11				
481	00JRP8455N	448057	5657348	1	11				
482	00JRP8455P	448057	5657348	2	22				
483	00JRP8456B	448156	5656542	4	41		1	i	l
484	00JRP8456C	448156	5656542	4	41		1	i	l
485	00JRP8457B	448531	5655290	7	72		3	i	u
486	00JRP8459B	448643	5655240	1	11		3	w	u
487	00JRP8461B	448472	5656729	7	72	i	123	i	u
488	00JRP8461D	448472	5656729	7	71	m	123	i	u
489	00JRP8462B	448487	5656864	2	21		12	w	u
490	00JRP8462E	448487	5656864	4	41	m	cb		
491	00JRP8462G	448487	5656864	4	41				
492	00JRP8462I	448487	5656864	7	72	i	13	i	u
493	00JRP8468B	449332	5658263	2	22	m			
494	00JRP8477B	450372	5657621	2	22	m			
495	00JRP8477C	450372	5657621	1	13	m			
496	00JRP8481B	450276	5657569	2	22				
497	00JRP8485B	448789	5661247	2	22	m			
498	00JRP8485D	448789	5661247	7	72	m	23	i	u
499	00JRP8485F	448789	5661247	7	79		3	i	u
500	00JRP8485G	448789	5661247	7	72		23	i	u
501	00JRP8485H	448789	5661247	7	72		3	i	u
502	00JRP8485I	448789	5661247	7	72		23	i	u
503	00JRP8485J	448789	5661247	7	72		23	i	u
504	00JRP8486B	447350	5655480	2	21				
505	00JRP8486D	447350	5655480	2	21				
506	00JRP8492B	442814	5657353	2	21				
507	00JRP8492D	442814	5657353	5	51				
508	00JRP8492E	442814	5657353	5	51				
509	00JRP9265	416328	5648723	6	62				
510	00JRP9279A	415899	5648248	7	73		3	i	l
511	00JRP9279B	415899	5648248	7	73		3	i	l
512	00JRP9280A	416382	5648778	7	73		3	i	l
513	00JRP9280B	416382	5648778	7	73		3	i	l
514	00JRP9280C	416382	5648778	1	13				
515	00JRP9438	423252	5653131	1	12		3	m	l
516	00JRP9453B	422899	5652596	7	43		3	i	l
517	00JRP9742B	430632	564445	6	62				
518	00JRP9743B	430588	5646744	6	69				
519	00JRP9746B	428808	5646673	6	62				
520	00JRP9748B	428818	5644499	8	80				
521	00JRP9749B	425794	5646477	8	80				
522	00JRP9750B	421805	5647862	8	80				
523	00JRP9751B	419812	5649498	8	80				
524	00JRP9752B	415352	5646347	8	80				
525	00JRP9756B	439805	5650612	2	29	i	4	m	l
526	00JRP9756D	439805	5650612	2	29		4	m	l
527	00JRP9756F	439805	5650612	6	62		12	w	ll

Reference Number	Sample Number	UTM Zone 15		Rock Association	Metamorphic Grade	Deformation	Alteration		
		Easting	Northing				type	intensity	timing
528	00JRP9756H	439805	5650612	7	71	i	13	i	u
529	00JRP9756J	439805	5650612	7	71	i	13	i	u
530	00JRP9758B	440346	5650457	7	71		13	i	u
531	00JRP9759B	434674	5645258	1	13				
532	00JRP9761B	434254	5645076	1	13				
533	00JRP9766B	434491	5644403	6	62		1	w	III
534	00JRP9767B	434473	5644527	1	13				
535	00JRP9768B	434330	5644375	1	13		1	w	III
536	00JRP9771B	439862	5652414	2	21				
537	00JRP9772B	439689	5652323	2	22				
538	00JRP9772C	439689	5652323	2	22				
539	00JRP9773B	439520	5652450	6	61				
540	00JRP9774B	439262	5652204	6	61				
541	00JRP9775B	439166	5652101	6	62				
542	00JRP9776B	438925	5651865	6	62				
543	00JRP9776D	438925	5651865	6	62				
544	00JRP9781B	437552	5645905	6	62				
545	00JRP9782B	436981	5645871	1	13				
546	00JRP9786B	436246	5645133	8	80				
547	00JRP9789B	436228	5644386	6	22				
548	00JRP9790B	436560	5645088	8	80				
549	00JRP9793B	434160	5644892	1	12				
550	00JRP9793D	434160	5644892	1	13				
551	00JRP9793I	434160	5644892	2	22				
552	00JRP9793J	434160	5644892	7	72				
553	00JRP9793K	434160	5644892	9	92		4	i	u
554	00JRP9794B	434734	5646158	3	32				
555	00JRP9794D	434734	5646158	1	13	m			
556	00JRP9794F	434734	5646158	4	43				
557	00JRP9794H	434734	5646158	7	73		3	i	I
558	00JRP9794K	434734	5646158	1	13				
559	00JRP9794L	434734	5646158	7	43		3	i	I
560	00JRP9794M	434734	5646158	1	13		3	i	I
561	00JRP9794N	434734	5646158	1	12				
562	00JRP9794O	434734	5646158	7	73		3	i	I
563	00JRP9794P	434734	5646158	1	13		3	i	I
564	00JRP9796B	434767	5646232	1	13				
565	00JRP9797B	434779	5646449	3	32				
566	00JRP9800B	433512	5644246	7	73		3	i	I
567	00JRP9801B	435837	5645517	2	22				
568	00JRP9813B	438177	5649338	1	12	m			
569	00JRP9815B	438470	5649500	1	12	i			
570	00JRP9837B	434050	5645506	3	32				
571	00JRP9839B	433138	5646329	8	80				
572	00JRP9842B	432599	5646092	8	80				
573	00JRP9847B	434337	5646469	3	32				
574	00JRP9848B	434529	5646606	3	31				
575	00JRP9850B	434589	5647019	3	32				
576	00JRP9853B	433996	5646934	1	13				
577	00JRP9853C	433996	5646934	1	13	m	4	w	I
578	00JRP9853D	433996	5646934	1	13		4	w	1

Reference Number	Sample Number	UTM Zone 15		Rock Association	Metamorphic Grade	Deformation	Alteration		
		Easting	Northing				type	intensity	timing
579	00JRP9857B	435105	5645822	1	43		1	i	I
580	00JRP9860B	435262	5645987	1	43		1	i	I
581	00JRP9862B	435371	5646217	3	32	i	1	m	III
582	00JRP9867B	444243	5650454	1	11				
583	00JRP9869B	445246	5650711	1	12				
584	00JRP9870B	446066	5650979	6	61	i	12	w	II
585	00JRP9871B	446200	5651090	6	61	i	12	w	II
586	00JRP9874B	446259	5651345	6	61		12	w	II
587	00JRP9874C	446259	5651345	9	99		45	i	u
588	00JRP9884B	454167	5670897	2	22				
589	00JRP9888B	451896	5666632	1	13	i			
590	00JRP9892	434886	5647929	3	32				
591	00JRP9898B	433952	5646876	1	13	m			
592	00JRP9899B	434075	5646920	3	31				
593	00JRP9901B	433848	5647564	1	13	m			
594	00JRP9915B	433784	5647305	1	13				
595	00JRP9929B	435014	5649548	2	22				
596	00JRP9929C	435014	5649548	2	22		45	i	III
597	00JRP9934B	435529	5649811	2	22				
598	00JRP9935D	435598	5649908	2	29				
599	00JRP9939B	435914	5650089	1	12				
600	00JRP9943B	434683	5649164	3	31				
601	00JRP9945B	433232	5651045	2	21				
602	00JRP9945D	433232	5651045	4	42		1	i	I
603	00JRP9946	433168	5650957	7	72		3	i	u
604	00JRP9969B	448937	5661178	1	12	m			
605	00JRP9969D	448937	5661178	1	12				
606	00JRP9970C	448709	5661276	2	12				
607	00JRP9970E	448709	5661276	1	12				
608	00JRP9970F	448709	5661276	1	12				
609	00JRP9970G	448709	5661276	5	52				
610	00JRP9970H	448709	5661276	5	52				
611	00JRP9970I	448709	5661276	5	12				
612	00JRP9970J	448709	5661276	5	12				
613	00JRP9978	448713	5662066	1	13				
614	00JRP9988B	447566	5661452	1	11	i	1	m	u
615	00JRP9988D	447566	5661452	2	22				
616	00JRP9998B	433248	5651687	1	11				
617	SNB-99-1001	433274	5654316	3	31				
618	SNB-99-1002	430626	5654389	3	31				
619	SNB-99-1003	427507	5655386	2	21	m			
620	SNB-99-1007B	445087	5664309	1	11				
621	SNB-99-1008H	445389	5664482	1	11				
622	SNB-99-1008L-1A	445389	5664482	3	32				
623	SNB-99-1008L-1B	445389	5664482	3	32				
624	SNB-99-1008L-2B	445389	5664482	3	32				
625	SNB-99-1008L-3A	445389	5664482	3	32				
626	SNB-99-1008L-3B	445389	5664482	3	32	i			
627	SNB-99-1008L-4A	445389	5664482	3	32				
628	SNB-99-1008L-5B	445389	5664482	3	32				
629	SNB-99-1010	432605	5654554	1	11				

Reference Number	Sample Number	UTM Zone 15		Rock Association	Metamorphic Grade	Deformation	Alteration		
		Easting	Northing				type	intensity	timing
630	SNB-99-1021B	433960	5657523	1	12	w			
631	SNB-99-1022	434672	5656233	2	21	m			
632	SNB-99-1038A	440054	5649505	2	22	i	4	w	l
633	SNB-99-1039A	440146	5649335	1	13		2	w	l
634	SNB-99-1041	436019	5646040	1	13	w			
635	SNB-99-1045	436212	5646290	1	13	m	3	w	l
636	SNB-99-1047	434751	5647059	3	32				
637	SNB-99-1048	434612	5646812	3	32				
638	SNB-99-1049	434328	5646513	3	32				
639	SNB-99-1051	433909	5646975	1	13	m			
640	SNB-99-1055	417586	5653917	1	12				
641	SNB-99-1056	417240	5654269	4	41		4	w	l
642	SNB-99-1060	416804	5659306	1	13				
643	SNB-99-1073	418983	5654376	2	29				
644	SNB-99-1082	416558	5658579	3	31				
645	SNB-99-1083B	416381	5657450	3	31				
646	SNB-99-1086	437789	5651357	1	12				
647	SNB-99-1087	435367	5651134	7	72	m	123	m	u
648	SNB-99-1091	434278	5650158	1	11		3	w	u
649	SNB-99-1097	439742	5654916	6	62				
650	SNB-99-1106	444118	5654588	1	11				
651	SNB-99-1110A	446917	5654474	1	11		3	m	u
652	SNB-99-1110C	446917	5654474	1	11				
653	SNB-99-1113	451129	5658453	2	22	m			
654	SNB-99-1119A	448117	5670329	2	22	m			
655	SNB-99-1123	443639	5668763	6	62	i			
656	SNB-99-1128	438717	5667592	6	62				
657	SNB-99-1134	429330	5657872	1	13				
658	SNB-99-1139	424106	5657569	1	13				
659	SNB-99-1141	446179	5665224	1	13				
660	SNB-99-1142A	445903	5664918	1	13				
661	SNB-99-1143A	445410	5664533	3	32				
662	SNB-99-1144	446267	5664723	7	72	i	23	m	u
663	SNB-99-1146A	447008	5665567	2	29	i			
664	SNB-99-1151A	448754	5666175	1	13	m			
665	SNB-99-1153	449076	5666205	1	13	i	3	w	ll
666	SNB-99-1156	449588	5666856	1	13	i			
667	SNB-99-1160	452998	5669293	2	22	m			
668	SNB-99-1166	443621	5656729	2	21	m			
669	SNB-99-1169C	442763	5657372	1	11				
670	SNB-99-1169D	442763	5657372	1	11				
671	SNB-99-1169E	442763	5657372	2	21	m			
672	SNB-99-1175	444582	5656393	1	11				
673	SNB-99-1176	444497	5656475	2	21				
674	SNB-99-1180	451011	5658331	1	11	m			
675	SNB-99-1181	453102	5660340	1	12	m			
676	SNB-99-1184	415036	5651913	1	11				
677	SNB-99-1187B	414652	5651579	2	21				
678	SNB-99-1188	414529	5651514	1	12				
679	SNB-99-1190	447550	5655250	2	29				
680	SNB-99-1192	410606	5658672	1	12	i			

Reference Number	Sample Number	UTM Zone 15		Rock Association	Metamorphic Grade	Deformation	Alteration		
		Easting	Northing				type	intensity	timing
681	SNB-99-1195	410441	5657889	2	22	m			
682	SNB-99-1197	410943	5657460	1	12	m			
683	SNB-99-1200	411797	5657843	2	22				
684	SNB-99-1202A	412288	5657930	3	31				
685	SNB-99-M2019	421852	5653425	1	12				
686	SNB-99-M2032	433458	5653208	1	11	i			
687	SNB-99-M2048B	441748	5663665	1	13		3	w	II
688	SNB-99-M2052A	434212	5644875	1	13	m	3	w	II
689	SNB-99-M2064B	423676	5652219	8	80				
690	SNB-99-M2075B	447709	5662958	1	12	m			
691	SNB-99-M2077	440445	5653627	6	62				
692	SNB-99-M2084	445523	5652577	6	61		13	w	I
693	SNB-99-M2088B	445700	5653250	6	61	m	13	w	II
694	SNB-99-M2109	436600	5661500	1	11	i			
695	SNB-99-M2117B	440068	5663759	1	12				
696	SNB-99-M2120	438700	5663500	6	61				
697	SNB-99-M2138B	415207	5650804	3	32	m			
698	SNB-99-M2139	415475	5650804	1	13				
699	SNB-99-M2142	413400	5659600	1	13				
700	SNB-99-M2145A	413300	5654800	1	12	i	13	m	u
701	SNB-99-M2145B	413300	5654800	1	12	i	13	m	I
702	SNB-99-M2148	435499	5647100	1	13				
703	SRB-99-004	429162	5655302	1	11	m	23	m	III
704	SRB-99-007	426331	5653923	1	13	m	3	w	I
705	SRB99-13a	424226	5654004	2	22	m			
706	SRB99-16a	421867	5652850	2	22	m			
707	SRB99-18	444576	5664196	2	22	m			
708	SRB-99-020	446606	5667621	1	13	m			
709	SRB99-30	439885	5665025	2	29	w			
710	SRB99-32a	435445	5645914	7	73	i			
711	SRB-99-032B	435445	5645914	1	13	m			
712	SRB-99-033	435139	5645540	2	22	m			
713	SRB99-35a	434040	5643766	2	22	m			
714	SRB-99-054	415674	5659406	1	13	m	3	w	I
715	SRB99-56a	414820	5659659	4	42	i	1	m	II
716	SRB99-56b	414820	5659659	7	73	n			
717	SRB-99-59B	412805	5658695	2	22	m			
718	SRB-99-062	421186	5653463	1	13	m			
719	SRB-99-64L-1A	421150	5653745	3	32				
720	SRB-99-64L-2A	421150	5653745	3	32				
721	SRB-99-64L-2B	421150	5653745	3	32				
722	SRB-99-64L-3A	421150	5653745	3	32				
723	SRB-99-64L-3B	421150	5653745	3	32				
724	SRB-99-64L-4A	421150	5653745	3	32				
725	SRB-99-64L-4B	421150	5653745	3	32				
726	SRB-99-64L-5A	421150	5653745	2	22				
727	SRB-99-64L-5B	421150	5653745	3	32				
728	SRB-99-64L-7A	421150	5653745	3	32				
729	SRB-99-64L-8A	421150	5653745	3	32				
730	SRB-99-065	419967	5653823	2	22	w			
731	SRB99-72a	413821	5656670	2	21	m			

Reference Number	Sample Number	UTM Zone 15		Rock Association	Metamorphic Grade	Deformation	Alteration		
		Easting	Northing				type	intensity	timing
732	SRB-99-072B	413821	5656670	2	21				
733	SRB99-76a	415291	5654254	2	22	m			
734	SRB-99-076B	415291	5654254	2	22	m			
735	SRB99-78a	413257	5654999	3	32	m			
736	SRB-99-78b	413257	5654999	1	11	w			
737	SRB99-81	430903	5655669	1	11	i	3	m	II
738	SRB-99-82b	426373	5655620	1	11				
739	SRB99-86i	435281	5645780	4	43	m	1	i	I
740	SRB99-86ii	435281	5645780	4	43	m	1	i	I
741	SRB99-86iii	435281	5645780	4	43	m	1	i	I
742	SRB99-87i	435273	5645914	2	22	m			
743	SRB-99-089A	435782	5646858	1	12	w			
744	SRB99-89b	435782	5646858	2	22	m			
745	SRB-99-089B	435782	5646858	2	29				
746	SRB-99-090B	435809	5647142	1	13				
747	SRB99-95	435262	5646216	2	22	m			
748	SRB99-97i	435263	5646008	4	43	m			
749	SRB99-97b-i	435263	5646008	4	43	m	1	w	II
750	SRB99-97b-ii	435263	5646008	4	43	m	1	w	II
751	SRB-99-097E	435263	5646008	1	12				
752	SRB-99-098A	434735	5646215	1	12				
753	SRB99-102	442046	5659881	5	52	w			
754	SRB99-104a	441671	5660288	2	29	m			
755	SRB-99-104B	441671	5660288	2	29				
756	SRB99-107	440772	5659306	2	22	w			
757	SRB-99-109	440947	5660913	1	11				
758	SRB-99-110	441797	5661038	1	11				
759	SRB99-112	441312	5660717	7	71	i	123	i	II
760	SRB-99-117	439914	5660293	2	21	i			
761	SRB99-121	440665	5660330	2	21	m			
762	SRB-99-121b	440665	5660330	2	21	i	2	m	II
763	SRB99-124i	446517	5643322	2	22	m			
764	SRB99-124ii	446517	5643322	2	22	m			
765	SRB99-134a	444783	5665380	2	22	m			
766	SRB99-135a	445009	5665045	2	22	m			
767	SRB99-135b	445009	5665045	4	41	m			
768	SRB-99-138	445153	5664414	1	11				
769	SRB-99-141	443631	5664188	1	11				
770	SRB-99-142	444509	5663838	2	22	m			
771	SRB-99-143	444136	5663644	2	22	m			
772	SRB-99-146	442674	5663717	1	11	w			
773	SRB-99-154	442417	5656276	2	21	i			
774	SRB-99-156	443500	5655646	2	22	m	1	w	III
775	SRB99-159	443053	5659607	2	21	m			
776	SRB-99-163B	443065	5659888	2	22	i			
777	SRB-99-168	441170	5659904	2	21	i			
778	SRB99-199b-i	435855	5646887	5	52	m			
779	SRB99-199b-ii	435855	5646887	5	52	m			
780	SRB-99-204	441318	5675711	8	80				
781	SRB-99-208B	437323	5669084	1	12	m	2	w	III
782	SRB99-2110f	439385	5665298	2	22	m			

Reference Number	Sample Number	UTM Zone 15		Rock Association	Metamorphic Grade	Deformation	Alteration		
		Easting	Northing				type	intensity	timing
783	SRB99-2110g	439385	5665298	2	22	m			
784	SRB00-4006i	416083	5649028	5	52	w			
785	SRB00-4006ii	416083	5649028	5	52	m			
786	SRB00-4037b	459291	5648378	2	22	m			
787	SRB00-4067f	449836	5653482	2	22	m			
788	SRB00-4065L-1A	419967	5653823	2	21				
789	SRB00-4065L-2A	419967	5653823	2	21				
790	SRB00-4065L-3A	419967	5653823	2	22				
791	SRB00-4065L-3B	419967	5653823	7	71		13	i	u
792	SRB00-4065L-4A	419967	5653823	2	22				
793	SRB00-4089	419814	5657942	7	73	m			
794	SRB00-4092	423149	5657802	1	12	n			
795	SRB00-4101b	443491	5659351	2	21	m			
796	SRB00-4116c	441525	5660464	7	71	i			
797	SRB00-4123	415803	5651825	1	11	n			
798	SRB00-4124b	415559	5651953	7	72	m			
799	SRB00-4129b	424560	5654688	1	11	m			
800	SRB00-4134a	421393	5655104	2	21	w			
801	SRB00-4134b	421393	5655104	2	21	m			
802	SRB00-4136	417403	5654183	2	29	m			

Table 2. Sample number, location (UTM datum NAD 1927), grade, 598 thin sections (indicated in Figure 2, back pocket). Gaps in reference numbers represent samples listed in Table 1 that were omitted from this table to remove duplication and simplify data on Figure 2.

Reference Number	Sample Number	UTM Zone 15 NAD27		Rock Association	Metamorphic Grade
		Easting	Northing		
1	76-16-29	438900	5662140	2	22
2	76-16-36	439245	5662525	1	13
3	76-16-39	439495	5662760	2	22
4	76-16-41	439660	5662975	7	72
5	76-16-49	440830	5662125	1	11
6	76-16-54	440850	5661965	2	22
7	76-16-65	445000	5664735	2	22
8	76-16-68	444885	5665065	5	52
9	76-16-75	445000	5666000	2	22
10	76-16-98	437545	5662150	2	21
11	76-16-124	442705	5663770	1	12
12	76-16-126	442670	5663865	1	11
13	76-16-137	443455	5663890	6	62
14	76-16-209	437105	5662745	1	12
15	76-16-212	440830	5664830	1	11
16	76-16-218	439885	5665060	2	22
17	76-16-220	440305	5665070	2	22
18	76-16-222	440450	5665030	5	52
19	76-16-233	445930	5664685	4	42
20	76-16-236	446005	5664440	7	72
21	76-16-238	446165	5664665	2	21
22	76-16-239	446185	5664570	2	22
23	76-16-240	446300	5664840	5	52
24	76-16-242	446350	5664885	4	42
25	76-16-250	446525	5667270	4	42
26	76-16-255	446265	5665345	1	11
27	76-16-257	446210	5665310	1	11
28	76-16-259	446290	5665230	1	12
30	76-16-262	438195	5663565	2	22
31	76-16-272	437150	5664485	2	22
32	76-16-278	437710	5665150	2	22
33	76-16-281	437175	5664850	6	62
34	76-16-284	439355	5664890	2	22
35	76-16-286	439235	5665485	4	42
36	76-16-287	439290	5665525	4	42
37	76-16-293	438610	5666335	4	42
38	76-16-294	438060	5666725	2	22
39	76-16-297	437445	5667300	6	62
40	76-16-319	440610	5664350	1	13
41	76-16-365	439075	5664435	6	62
42	76-16-401	438615	5667415	2	22
43	76-16-402	438550	5667455	2	22
44	76-16-408	441000	5663920	2	22
45	76-16-603	437600	5670000	6	62
46	76-16-609	446590	5669130	2	22
47	76-16-610	446685	5669475	6	62
48	76-16-611	446685	5669930	6	62

Reference Number	Sample Number	UTM Zone 15 NAD27		Rock Association	Metamorphic Grade
		Easting	Northing		
49	76-16-615	445370	5664520	3	32
57	76-16-637	443275	5662105	2	21
58	76-16-638	443245	5662060	7	71
59	76-16-654	439555	5667505	2	22
60	76-16-656	439665	5667705	2	22
61	76-16-659	440210	5667950	2	22
62	76-16-676	442460	5662045	1	11
63	76-16-680	443290	5665590	1	12
64	76-16-683	446420	5666550	1	12
65	76-16-693	445430	5663645	2	22
66	76-16-696	446000	5663635	3	31
67	76-16-723	440070	5665910	4	42
68	76-16-730	441090	5667275	4	42
69	76-16-746	440260	5669115	1	13
70	76-16-771	445070	5661910	3	31
71	76-16-803	445925	5664940	1	12
72	76-16-817	444785	5661845	1	11
73	76-16-821	446465	5663950	2	21
74	76-16-822	446600	5663935	2	22
75	76-16-825	443910	5662045	7	71
76	76-16-827	447045	5665095	2	22
77	76-16-833	445725	5667880	1	12
78	76-16-911	443550	5662575	4	42
79	76-16-1002	446850	5665450	2	21
80	76-16-1004	446965	5665580	2	22
81	76-16-1005	446970	5665585	2	22
82	76-16-1006	447365	5666115	2	22
83	76-16-1007	447455	5666120	2	22
84	76-16-1008	447525	5666115	4	42
86	76-16-1011	451130	5665665	1	13
87	76-16-1014	451920	5664990	7	72
88	76-16-1015	451885	5664615	1	11
89	76-16-1017	454035	5669475	1	13
90	76-16-1022	447795	5666165	2	22
91	76-16-1023	447720	5666285	5	52
92	76-16-1024	447725	5666345	2	22
93	76-16-1026	448245	5666250	1	12
94	76-16-1027	448740	5666190	1	11
96	76-16-1031	453375	5657405	1	11
97	76-16-1035	453605	5657585	7	72
98	76-16-1036	453885	5658730	3	32
99	76-16-1041	455150	5668225	8	80
100	76-16-1047	455540	5667785	6	62
101	76-16-1060	447120	5664895	2	22
103	76-16-1063	447195	5665245	2	22
104	76-16-1065	449875	5665945	6	62
105	76-16-1069	447895	5668905	7	73
106	76-16-1070	448235	5669695	7	73
107	76-16-1071	448350	5670160	2	22
108	76-16-1073	453620	5663955	7	73
109	76-16-1078	452395	5666135	2	22

Reference Number	Sample Number	UTM Zone 15 NAD27		Rock Association	Metamorphic Grade
		Easting	Northing		
110	76-16-1085	453635	5661495	1	13
111	76-16-1086	453645	5661575	5	52
112	76-16-1087	453605	5661895	1	13
113	76-16-1091	453590	5660650	1	13
114	76-16-1095	447530	5663800	2	22
115	76-16-1098	447740	5663925	1	12
116	76-16-1101	449705	5664040	1	13
117	76-16-1107	449285	5664150	3	32
118	76-16-1128	454955	5669145	8	80
119	76-16-1138	450915	5663270	2	22
120	76-16-1144	447905	5667730	2	22
121	76-16-1145	447040	5668150	2	22
122	76-16-1153	453210	5663265	1	13
123	76-16-1154	453350	5663305	1	13
124	76-16-1175	454285	5664995	1	13
125	76-16-1181	455735	5663400	8	80
126	76-16-1187	448145	5667005	2	22
127	76-16-1191	447735	5666790	3	32
128	76-16-1193	448065	5666735	5	52
129	76-16-1194	449240	5666135	1	12
130	76-16-1202	448345	5664220	7	72
131	76-16-1203	448365	5664055	1	12
132	76-16-1206	455895	5657335	1	12
133	76-16-1207	455900	5657335	1	12
134	76-16-1210	448275	5663740	7	72
135	76-16-1211	448255	5663625	3	32
136	76-16-1213	448035	5663410	1	12
137	76-16-1215	450245	5656165	1	12
138	76-16-1218	451220	5655505	1	12
139	76-16-1219	451105	5655430	1	11
140	76-16-1226	450310	5653735	7	72
141	76-16-1233	447245	5654710	7	71
142	76-16-1234	447245	5654710	7	71
143	76-16-1235	453875	5658590	1	11
144	76-16-1241	455090	5660345	1	12
145	76-16-1242	454960	5660190	1	13
146	76-16-1244	453090	5660175	1	12
147	76-16-1252	449945	5657630	2	22
148	76-16-1253	450810	5657770	4	43
149	76-16-1307	449345	5666320	2	22
150	76-16-1314	449645	5655990	2	21
151	76-16-1323	449360	5653935	2	22
152	76-16-1328	453305	5659445	1	13
153	76-16-1337	455110	5653365	1	13
154	76-16-1345	453855	5652965	1	12
155	76-16-1353	452880	5657395	1	12
156	76-16-1379	451225	5667800	1	13
157	76-16-1385	449245	5658040	1	13
158	76-16-1395	448170	5656560	4	42
159	76-16-1403	448630	5665200	5	52
160	76-16-1408	451670	5654815	1	13

Reference Number	Sample Number	UTM Zone 15 NAD27		Rock Association	Metamorphic Grade
		Easting	Northing		
161	76-16-1415	450625	5657815	1	13
162	76-16-1424	448325	5657765	3	31
163	76-16-1426	448610	5657180	7	72
164	76-16-1431	449040	5657625	1	11
165	76-16-1432	449100	5658215	2	22
166	76-16-1437	448485	5656935	2	21
167	76-16-1438	448475	5656670	7	72
168	76-16-1446	447290	5655430	7	71
169	76-16-1448	447505	5655430	2	21
170	76-16-1458	446765	5652765	1	11
171	76-16-1477	448005	5656500	1	11
172	76-16-1478	447030	5656190	2	21
173	76-16-1485	454890	5652320	1	12
174	76-16-1508	449510	5656960	1	12
175	76-16-1604A	446870	5664995	1	12
177	79-PR-01	440685	5649340	1	13
178	79-PR-02	441720	5649105	2	22
179	79-PR-04	440830	5648910	2	22
180	79-PR-06	440710	5649480	1	11
181	79-PR-07	441090	5649315	2	22
182	79-PR-11	439165	5647120	2	22
183	79-PR-13	438805	5647000	2	22
184	79-PR-15	440110	5651320	6	62
185	79-PR-19	439485	5646820	2	22
186	79-PR-22	439890	5646235	7	73
187	79-PR-24	440810	5646480	1	13
188	79-PR-25	440115	5646255	1	13
189	79-PR-28	441300	5648510	2	22
190	79-PR-29A	441665	5648420	2	22
191	79-PR-30	437370	5648000	7	72
192	79-PR-31	437645	5648010	1	13
193	79-PR-35	437240	5647290	6	62
194	79-PR-37	445620	5643240	2	22
195	79-PR-38	445419	5643220	1	13
196	79-PR-46	438880	5642885	2	21
197	79-PR-52	439560	5648890	2	22
198	79-PR-54	439840	5649195	1	11
199	79-PR-55	440325	5649790	2	22
200	79-PR-56	440410	5649885	2	22
201	79-PR-58	440680	5650195	2	22
203	79-PR-63	438420	5643000	7	72
204	79-PR-64	438390	5643620	2	22
205	79-PR-65	438275	5643340	1	13
206	79-PR-69	442955	5642815	7	73
207	79-PR-70	442915	5642965	2	22
208	79-PR-72	442950	5643125	1	11
209	79-PR-77	442815	5648215	7	73
210	79-PR-79	442000	5648145	2	22
211	79-PR-83	437020	5645090	6	62
212	79-PR-87	444490	5648970	1	11
213	79-PR-88	444495	5649220	2	22

Reference Number	Sample Number	UTM Zone 15 NAD27		Rock Association	Metamorphic Grade
		Easting	Northing		
214	79-PR-89	444540	5649165	2	22
215	79-PR-91	440475	5648580	2	22
216	79-PR-93	440710	5648380	1	12
217	79-PR-94	440845	5647870	2	22
218	79-PR-112	437845	5646775	2	22
219	79-PR-117	437620	5645845	6	62
220	79-PR-137A	438755	5649020	1	12
221	79-PR-140A	439250	5648630	1	12
222	79-PR-140B	439250	5648630	2	22
223	79-PR-149	440820	5647430	2	22
224	79-PR-161	437695	5648790	1	12
225	79-PR-170	438225	5646795	2	22
226	79-PR-172	438265	5646580	2	22
236	98JRP0007Y	414961	5650574	1	13
237	98JRP0011A	415195	5650607	1	13
243	98JRP0027B	444450	5649131	2	22
244	98JRP0037B	440373	5649758	2	22
245	98JRP0042B	440785	5650285	2	22
246	98JRP0053B	440184	5648480	2	22
247	98JRP0057B	440538	5648092	2	22
248	98JRP0074B	449533	5647186	2	22
249	98JRP0075B	452948	5647040	2	22
250	98JRP0078B	411602	5658849	2	22
251	98JRP0084B	413623	5658122	2	21
252	98JRP0086B	413237	5657627	2	22
253	98JRP0087B	413769	5656655	2	21
254	98JRP0089B	416547	5654893	2	22
255	98JRP0090B	416817	5654643	2	22
257	98JRP0111B	445513	5642805	2	22
278	99JRP9188C	444632	5646161	2	22
279	99JRP9192B	444235	5646901	2	22
280	99JRP9194B	444081	5647166	2	22
281	99JRP9195B	444057	5647231	2	22
282	99JRP9196C	444010	5647316	2	22
283	99JRP9198B	443838	5647636	1	13
284	99JRP9279C	415899	5648248	7	73
285	99JRP9294B	416259	5650098	2	22
286	99JRP9295B	415664	5649375	1	11
287	99JRP9298B	415161	5649249	1	11
288	99JRP9306B	414837	5650034	2	22
289	99JRP9315C	414334	5650570	1	13
290	99JRP9320C	415378	5650437	1	12
291	99JRP9321B	415312	5650452	1	11
292	99JRP9352B	415166	5650288	1	12
293	99JRP9356C	415465	5650300	1	11
294	99JRP9363B	415458	5649640	4	43
295	99JRP9366B	415185	5649640	1	12
296	99JRP9371B	435453	5645793	2	22
298	99JRP9395B	413701	5651372	2	22
300	99JRP9399C	414969	5650571	1	11
301	99JRP9411B	426527	5655828	1	11

Reference Number	Sample Number	UTM Zone 15 NAD27		Rock Association	Metamorphic Grade
		Easting	Northing		
302	99JRP9417B	429068	5655169	7	71
303	99JRP9429B	423779	5654710	1	12
304	99JRP9437B	423267	5653189	2	22
305	99JRP9444B	423423	5654492	1	13
307	99JRP9480B	426970	5654040	1	13
308	99JRP9482B	427000	5654353	1	13
309	99JRP9484C	426997	5654171	1	13
310	99JRP9485C	427088	5654253	1	22
311	99JRP9505C	423870	5653493	7	73
312	99JRP9522D	413525	5656639	1	12
313	99JRP9526B	426201	5656094	1	11
314	99JRP9537B	424696	5657314	2	22
316	99JRP9551B	421392	5657600	6	61
317	99JRP9556C	426037	5656411	1	11
318	99JRP9557B	426081	5656358	1	11
319	99JRP9558B	426263	5656367	1	11
320	99JRP9564B	425358	5656604	1	11
321	99JRP9584C	420590	5657851	1	12
322	99JRP9586B	420525	5657947	1	12
323	99JRP9587B	420417	5657940	1	11
324	99JRP9592C	418976	5657592	1	11
326	99JRP9611	421526	5657398	2	22
327	99JRP9613B	419902	5657848	2	22
328	99JRP9621B	419847	5657956	2	22
329	99JRP9622B	419814	5657878	2	22
330	97JRP9624B	419857	5658073	6	62
331	99JRP9627B	419317	5658439	1	13
334	99JRP9629B	419808	5658244	1	11
339	99JRP9642B	419519	5655807	2	21
341	99JRP9644B	421193	5656240	2	21
342	99JRP9649C	421078	5656153	2	21
343	99JRP9650B	421029	5656060	2	21
344	99JRP9663B	430205	5658252	2	22
345	99JRP9669B	431180	5657897	1	12
346	99JRP9671E	431309	5657904	1	13
347	99JRP9682B	414487	5653964	7	71
350	99JRP9690B	417521	5654290	6	62
351	99JRP9696D	433567	5658820	2	22
352	99JRP9696F	433567	5658820	2	22
353	99JRP9700B	433597	5658956	2	22
354	99JRP9701B	437048	5661410	2	22
355	99JRP9702C	436531	5660415	2	22
356	99JRP9708B	411655	5656013	2	22
357	99JRP9736B	412782	5655025	1	12
358	00JRP8020B	435903	5651021	7	71
359	00JRP8028B	436339	5650937	7	72
360	00JRP8035B	444825	5657929	7	71
361	00JRP8036B	444864	5658116	6	62
362	00JRP8038B	444952	5658086	1	11
363	00JRP8058B	445293	5659748	7	71
364	00JRP8060B	445338	5659799	2	21

Reference Number	Sample Number	UTM Zone 15 NAD27		Rock Association	Metamorphic Grade
		Easting	Northing		
366	00JRP8064B	445036	5660224	1	11
367	00JRP8068B	444538	5660423	7	71
368	00JRP8071B	443640	5658461	7	71
371	00JRP8072F	443703	5658411	2	21
375	00JRP8076B	443890	5658513	7	71
376	00JRP8077B	444017	5658554	7	71
377	00JRP8092B	444495	5661078	1	12
378	00JRP8093B	446297	5652424	1	13
379	00JRP8097B	446435	5652858	1	12
380	00JRP8105B	446420	5653117	2	22
381	00JRP8107B	446145	5653457	1	12
382	00JRP8108B	445996	5653009	2	22
383	00JRP8108D	445912	5653113	2	22
384	00JRP8111B	434029	5647419	1	12
386	00JRP8157B	447723	5663943	1	12
387	00JRP8164B	446602	5662214	7	72
388	00JRP8168B	447010	5659422	7	72
389	00JRP8174B	448844	5660444	2	22
390	00JRP8176B	449365	5660655	1	13
391	00JRP8182B	450871	5663043	2	22
392	00JRP8199A	455412	5659897	1	13
394	00JRP8201B	456208	5659938	8	80
395	00JRP8202B	456763	5661908	8	80
396	00JRP8204B	456763	5662980	8	80
397	00JRP8205B	451113	5658445	1	13
398	00JRP8213B	452055	5659175	4	43
400	00JRP8214C	452114	5659125	4	43
401	00JRP8218B	451356	5665712	1	13
402	00JRP8220B	451329	5665845	3	32
405	00JRP8227B	455324	5670180	4	43
407	00JRP8230A	456049	5671017	5	52
408	00JRP8232A	450972	5654802	2	22
410	00JRP8243B	452613	5654126	1	13
411	00JRP8246B	445264	5654297	1	11
412	00JRP8247B	445481	5654269	5	52
413	00JRP8248B	446417	5654392	1	11
415	00JRP8250B	449426	5664088	5	52
416	00JRP8251B	449552	5664091	7	72
417	00JRP8252B	449319	5663952	7	72
419	00JRP8256B	447173	5664982	7	72
420	00JRP8257B	446177	5664632	2	21
421	00JRP8259B	445456	5664771	7	72
422	00JRP8276B	441798	5661042	1	11
423	00JRP8284B	440865	5660402	2	21
424	00JRP8286B	440491	5660529	7	71
425	00JRP8287B	440425	5660628	5	22
426	00JRP8288B	439930	5660316	2	21
427	00JRP8291B	441509	5660379	2	21
429	00JRP8292B	441605	5660289	2	21
430	00JRP8306B	447995	5653149	2	21
431	00JRP8307B	447854	5652906	1	12

Reference Number	Sample Number	UTM Zone 15 NAD27		Rock Association	Metamorphic Grade
		Easting	Northing		
432	00JRP8308B	447784	5652787	1	13
433	00JRP8320C	442057	5660187	7	72
435	00JRP8322F	442274	5660276	2	22
437	00JRP8346B	443391	5658751	4	43
438	00JRP8348B	443088	5658674	4	43
439	00JRP8355B	446171	5653635	7	71
441	00JRP8358D	442883	5654250	6	61
442	00JRP8370B	433882	5655139	7	73
443	00JRP8371B	434027	5655246	7	73
444	00JRP8372B	434146	5654572	6	62
445	00JRP8376B	428911	5653504	2	22
446	00JRP8378	428179	5653689	7	72
447	00JRP8379	430848	5653410	1	11
448	00JRP8391B	427580	5653583	8	80
449	00JRP8392B	428113	5653688	1	12
451	00JRP8397B	428919	5653582	7	72
452	00JRP8401B	421156	5652913	8	80
453	00JRP8402	419694	5653256	1	12
454	00JRP8406C	422322	5655459	5	52
455	00JRP8408B	421083	5653316	7	73
456	00JRP8417B	438119	5663016	2	22
457	00JRP8426B	446942	5654463	1	11
461	00JRP8427J	415310	5650466	1	12
463	00JRP8428D	415378	5650637	3	32
466	00JRP8429F	414844	5651034	1	12
470	00JRP8431D	447275	5655352	7	71
471	00JRP8432B	443567	5656683	4	41
473	00JRP8434B	443648	5657384	2	21
478	00JRP8455H	448057	5657348	1	11
483	00JRP8456B	448156	5656542	4	41
484	00JRP8456C	448156	5656542	4	41
485	00JRP8457B	448531	5655290	7	72
486	00JRP8459B	448643	5655240	1	11
487	00JRP8461B	448472	5656729	7	72
489	00JRP8462B	448487	5656864	2	21
493	00JRP8468B	449332	5658263	2	22
495	00JRP8477C	450372	5657621	1	13
496	00JRP8481B	450276	5657569	2	22
497	00JRP8485B	448789	5661247	2	22
504	00JRP8486B	447350	5655480	2	21
506	00JRP8492B	442814	5657353	2	21
509	00JRP9265	416328	5648723	6	62
510	00JRP9279A	415899	5648248	7	73
514	00JRP9280C	416382	5648778	1	13
515	00JRP9438	423252	5653131	1	12
516	00JRP9453B	422899	5652596	7	43
517	00JRP9742B	430632	5644445	6	62
519	00JRP9746B	428808	5646673	6	62
520	00JRP9748B	428818	5644499	8	80
521	00JRP9749B	425794	5646477	8	80
522	00JRP9750B	421805	5647862	8	80

Reference Number	Sample Number	UTM Zone 15 NAD27		Rock Association	Metamorphic Grade
		Easting	Northing		
523	00JRP9751B	419812	5649498	8	80
524	00JRP9752B	415352	5646347	8	80
528	00JRP9756H	439805	5650612	7	71
530	00JRP9758B	440346	5650457	7	71
531	00JRP9759B	434674	5645258	1	13
532	00JRP9761B	434254	5645076	1	13
533	00JRP9766B	434491	5644403	6	62
534	00JRP9767B	434473	5644527	1	13
535	00JRP9768B	434330	5644375	1	13
536	00JRP9771B	439862	5652414	2	21
537	00JRP9772B	439689	5652323	2	22
539	00JRP9773B	439520	5652450	6	61
540	00JRP9774B	439262	5652204	6	61
541	00JRP9775B	439166	5652101	6	62
542	00JRP9776B	438925	5651865	6	62
544	00JRP9781B	437552	5645905	6	62
545	00JRP9782B	436981	5645871	1	13
546	00JRP9786B	436246	5645133	8	89
547	00JRP9789B	436228	5644386	6	22
548	00JRP9790B	436560	5645088	8	80
550	00JRP9793D	434160	5644892	1	13
555	00JRP9794D	434734	5646158	1	13
564	00JRP9796B	434767	5646232	1	13
566	00JRP9800B	433512	5644246	7	73
567	00JRP9801B	435837	5645517	2	22
568	00JRP9813B	438177	5649338	1	12
569	00JRP9815B	438470	5649500	1	12
570	00JRP9837B	434050	5645506	3	32
571	00JRP9839B	433138	5646329	8	80
572	00JRP9842B	432599	5646092	8	80
573	00JRP9847B	434337	5646469	3	32
574	00JRP9848B	434529	5646606	3	31
575	00JRP9850B	434589	5647019	3	32
576	00JRP9853B	433996	5646934	1	13
579	00JRP9857B	435105	5645822	1	43
580	00JRP9860B	435262	5645987	1	43
581	00JRP9862B	435371	5646217	3	32
582	00JRP9867B	444243	5650454	1	11
583	00JRP9869B	445246	5650711	1	12
584	00JRP9870B	446066	5650979	6	61
585	00JRP9871B	446200	5651090	6	61
586	00JRP9874B	446259	5651345	6	61
588	00JRP9884B	454167	5670897	2	22
589	00JRP9888B	451896	5666632	1	13
590	00JRP9892	434886	5647929	3	32
591	00JRP9898B	433952	5646876	1	13
592	00JRP9899B	434075	5646920	3	31
593	00JRP9901B	433848	5647564	1	13
594	00JRP9915B	433784	5647305	1	13
595	00JRP9929B	435014	5649548	2	22
597	00JRP9934B	435529	5649811	2	22

Reference Number	Sample Number	UTM Zone 15 NAD27		Rock Association	Metamorphic Grade
		Easting	Northing		
599	00JRP9939B	435914	5650089	1	12
600	00JRP9943B	434683	5649164	3	31
602	00JRP9945D	433232	5651045	4	42
603	00JRP9946	433168	5650957	7	72
604	00JRP9969B	448937	5661178	1	12
608	00JRP9970F	448709	5661276	1	12
613	00JRP9978	448713	5662066	1	13
614	00JRP9988B	447566	5661452	1	11
617	SNB-99-1001	433274	5654316	3	31
618	SNB-99-1002	430626	5654389	3	31
619	SNB-99-1003	427507	5655386	2	21
620	SNB-99-1007B	445087	5664309	1	11
621	SNB-99-1008H	445389	5664482	1	11
629	SNB-99-1010	432605	5654554	1	11
630	SNB-99-1021B	433960	5657523	1	12
631	SNB-99-1022	434672	5656233	2	21
632	SNB-99-1038A	440054	5649505	2	22
633	SNB-99-1039A	440146	5649335	1	13
634	SNB-99-1041	436019	5646040	1	13
635	SNB-99-1045	436212	5646290	1	13
636	SNB-99-1047	434751	5647059	3	32
637	SNB-99-1048	434612	5646812	3	32
638	SNB-99-1049	434328	5646513	3	32
639	SNB-99-1051	433909	5646975	1	13
640	SNB-99-1055	417586	5653917	1	12
641	SNB-99-1056	417240	5654269	4	41
642	SNB-99-1060	416804	5659306	1	13
644	SNB-99-1082	416558	5658579	3	31
645	SNB-99-1083B	416381	5657450	3	31
646	SNB-99-1086	437789	5651357	1	12
647	SNB-99-1087	435367	5651134	7	72
648	SNB-99-1091	434278	5650158	1	11
649	SNB-99-1097	439742	5654916	6	62
650	SNB-99-1106	444118	5654588	1	11
651	SNB-99-1110A	446917	5654474	1	11
653	SNB-99-1113	451129	5658453	2	22
654	SNB-99-1119A	448117	5670329	2	22
655	SNB-99-1123	443639	5668763	6	62
656	SNB-99-1128	438717	5667592	6	62
657	SNB-99-1134	429330	5657872	1	13
658	SNB-99-1139	424106	5657569	1	13
659	SNB-99-1141	446179	5665224	1	13
660	SNB-99-1142A	445903	5664918	1	13
661	SNB-99-1143A	445410	5664533	3	32
662	SNB-99-1144	446267	5664723	7	72
664	SNB-99-1151A	448754	5666175	1	13
665	SNB-99-1153	449076	5666205	1	13
666	SNB-99-1156	449588	5666856	1	13
667	SNB-99-1160	452998	5669293	2	22
668	SNB-99-1166	443621	5656729	2	21
669	SNB-99-1169C	442763	5657372	1	11

Reference Number	Sample Number	UTM Zone 15 NAD27		Rock Association	Metamorphic Grade
		Easting	Northing		
672	SNB-99-1175	444582	5656393	1	11
673	SNB-99-1176	444497	5656475	2	21
674	SNB-99-1180	451011	5658331	1	11
675	SNB-99-1181	453102	5660340	1	12
676	SNB-99-1184	415036	5651913	1	11
677	SNB-99-1187B	414652	5651579	2	21
678	SNB-99-1188	414529	5651514	1	12
680	SNB-99-1192	410606	5658672	1	12
681	SNB-99-1195	410441	5657889	2	22
682	SNB-99-1197	410943	5657460	1	12
683	SNB-99-1200	411797	5657843	2	22
684	SNB-99-1202A	412288	5657930	3	31
685	SNB-99-M2019	421852	5653425	1	12
686	SNB-99-M2032	433458	5653208	1	11
687	SNB-99-M2048B	441748	5663665	1	13
688	SNB-99-M2052A	434212	5644875	1	13
689	SNB-99-M2064B	423676	5652219	8	80
690	SNB-99-M2075B	447709	5662958	1	12
691	SNB-99-M2077	440445	5653627	6	62
692	SNB-99-M2084	445523	5652577	6	61
693	SNB-99-M2088B	445700	5653250	6	61
694	SNB-99-M2109	436600	5661500	1	11
695	SNB-99-M2117B	440068	5663759	1	12
696	SNB-99-M2120	438700	5663500	6	61
697	SNB-99-M2138B	415207	5650804	3	32
698	SNB-99-M2139	415475	5650804	1	13
699	SNB-99-M2142	413400	5659600	1	13
700	SNB-99-M2145A	413300	5654800	1	12
702	SNB-99-M2148	435499	5647100	1	13
703	SRB-99-004	429162	5655302	1	11
704	SRB-99-007	426331	5653923	1	13
705	SRB99-13a	424226	5654004	2	22
706	SRB99-16a	421867	5652850	2	22
707	SRB99-18	444576	5664196	2	22
708	SRB-99-020	446606	5667621	1	13
711	SRB-99-032B	435445	5645914	1	13
712	SRB-99-033	435139	5645540	2	22
713	SRB99-35a	434040	5643766	2	22
714	SRB-99-054	415674	5659406	1	13
715	SRB99-56a	414820	5659659	4	42
717	SRB-99-59B	412805	5658695	2	22
718	SRB-99-062	421186	5653463	1	13
726	SRB-99-64L-5A	421150	5653745	2	22
730	SRB-99-065	419967	5653823	2	22
731	SRB99-72a	413821	5656670	2	21
733	SRB99-76a	415291	5654254	2	22
736	SRB-99-78b	413257	5654999	1	11
737	SRB99-81	430903	5655669	1	11
738	SRB-99-82b	426373	5655620	1	11
739	SRB99-86i	435281	5645780	4	43
742	SRB99-87i	435273	5645914	2	22

Reference Number	Sample Number	UTM Zone 15 NAD27		Rock Association	Metamorphic Grade
		Easting	Northing		
743	SRB-99-089A	435782	5646858	1	12
746	SRB-99-090B	435809	5647142	1	13
747	SRB99-95	435262	5646216	2	22
751	SRB-99-097E	435263	5646008	1	12
752	SRB-99-098A	434735	5646215	1	12
753	SRB99-102	442046	5659881	5	52
756	SRB99-107	440772	5659306	2	22
757	SRB-99-109	440947	5660913	1	11
758	SRB-99-110	441797	5661038	1	11
759	SRB99-112	441312	5660717	7	71
760	SRB-99-117	439914	5660293	2	21
761	SRB99-121	440665	5660330	2	21
763	SRB99-124i	446517	5643322	2	22
765	SRB99-134a	444783	5665380	2	22
766	SRB99-135a	445009	5665045	2	22
768	SRB-99-138	445153	5664414	1	11
769	SRB-99-141	443631	5664188	1	11
770	SRB-99-142	444509	5663838	2	22
771	SRB-99-143	444136	5663644	2	22
772	SRB-99-146	442674	5663717	1	11
773	SRB-99-154	442417	5656276	2	21
774	SRB-99-156	443500	5655646	2	22
775	SRB99-159	443053	5659607	2	21
776	SRB-99-163B	443065	5659888	2	22
777	SRB-99-168	441170	5659904	2	21
778	SRB99-199b-i	435855	5646887	5	52
780	SRB-99-204	441318	5675711	8	80
781	SRB-99-208B	437323	5669084	1	12
782	SRB99-2110f	439385	5665298	2	22
784	SRB00-4006i	416083	5649028	5	52
786	SRB00-4037b	459291	5648378	2	22
787	SRB00-4067f	449836	5653482	2	22
790	SRB00-4065L-3A	419967	5653823	2	22
793	SRB00-4089	419814	5657942	7	73
794	SRB00-4092	423149	5657802	1	12
795	SRB00-4101b	443491	5659351	2	21
796	SRB00-4116c	441525	5660464	7	71
797	SRB00-4123	415803	5651825	1	11
798	SRB00-4124b	415559	5651953	7	72
799	SRB00-4129b	424560	5654688	1	11
800	SRB00-4134a	421393	5655104	2	21

Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
<i>SI Unit</i>	<i>Multiplied by</i>	<i>Gives</i>	<i>Imperial Unit</i>	<i>Multiplied by</i>	<i>Gives</i>
LENGTH					
1 mm	0.039 37	inches	1 inch	25.4	mm
1 cm	0.393 70	inches	1 inch	2.54	cm
1 m	3.280 84	feet	1 foot	0.304 8	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	1.609 344	km
AREA					
1 cm ²	0.155 0	square inches	1 square inch	6.451 6	cm ²
1 m ²	10.763 9	square feet	1 square foot	0.092 903 04	m ²
1 km ²	0.386 10	square miles	1 square mile	2.589 988	km ²
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
VOLUME					
1 cm ³	0.061 023	cubic inches	1 cubic inch	16.387 064	cm ³
1 m ³	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m ³
1 m ³	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m ³
CAPACITY					
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	4.546 090	L
MASS					
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	31.103 476 8	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	0.453 592 37	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	907.184 74	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	0.907 184 74	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	1016.046 908 8	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	1.016 046 90	t
CONCENTRATION					
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	<i>Multiplied by</i>	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.